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Application of Precision Livestock Farming and Duties in Stabilizing Mini-livestock Welfare

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ABSTRACT

Mammalian mini-livestock production in Nigeria has become the fastest growing practice of food making intended to address the peoples' daily-recommended intake of animal protein foreseen by the Livestock Revolution. This sparks swift progression in production capacity for economic yield because its production currently stands as alternative sources to conventional animal protein. As the scale of production increases, it becomes pertinent to include precision livestock farming (PLF) technologies into its production to upturn the breeders' capability to remotely monitor, regulate and document biological processes involved in the livestock production in order to uphold ethically sound, fruitful and ecologically responsive production of mammalian mini-livestock. Adapting and using appropriate sensors such as cameras, microphones, accelerometers, and others via images, sounds and movements with algorithms would monitor livestock and their welfare. This process can boost the livestock performance, economic performance, and labour efficiency. Therefore, this paper reviewed the premise of quantitative remote observing of livestock and timely alerts of poor conditions of livestock welfare that require the attention of the breeders/farmers using the various PLF technologies or devices. It also offered important skills for mammalian mini-livestock breeders to translate mini-livestock data into the livestock health and well-being indices using algorithms and machine learning that are in line with the livestock industry welfare audit criteria. Therefore, the awareness to transfer PLF technologies and its implications to mini-livestock farmers would create possibilities for interconnection to expand its value chain where both customers and farmers are ultimately linked. That is, customers would make judgements based on ranch house practices, and farmers can as well take resolutions built on consumer practices.

Keywords: Mammalian mini-livestock; precision livestock farming; remote monitoring; management; welfare criteria; stakeholders

INTRODUCTION

Precision livestock farming (PLF) is a new model in livestock *o* husbandry that employs information tools and managing procedures to enhance *o* cost-effective, social, and eco-friendly ranch growth by decreasing losses, growing the animal product worth, boosting existing resources for complete productivity, and accurately meeting individual livestock nutrient needs (Lovato et al., 2017; White & Capper , 2014). The use of PLF encourages modern and large-scale ranches to replicate, and at a large scale, make it possible for caring farmers to identify animals that require attention. Hence, PLF is a suite of technology that uses networked devices to endlessly observe individual livestock in large ranch house, compare the data to predictable norms, and use algorithms to achieve single livestock' responses to deviations in weather, feeding, or reproductive decisions impulsively.

The use of PLF promotes livestock welfare, as fewer contacts with humans is required. For animals like mini-livestock, less contact with people is required for their comfort and improvement. Mammalian mini-livestock can respond with fear to human existence, as they are not comfortable to consistent human contacts. In a system where frequent human contact with livestock is not established, intermittent and uneven interfaces with humans produce distress in the livestock that may result in livestock welfare harms (production harms) and possible harm to breeders (injuries) (Munksgaard et al., 2001). The use of PLF operates on an automated system that responds speedily to temperature variations and handles a limitless number of livestock at a given ample arithmetical power (Werkheiser, 2018). Intriguingly, decision algorithms study quickly over time to create estimates and links amongst variables that human beings may not observe.

PLF encourages livestock farmers to constantly monitor their livestock and mediate immediately they show the initial symptoms of weakened wellbeing or pathologies. Speedy mediation to disease control or adjustment in managing trauma essentially and effectively improve livestock status. Consequently, the prolific performance that depend on animal fitness and wellbeing is realized via PLF with the mitigated ecological influence of livestock in the direction of reducing the occurrence and spread of resistant bacteria in the environs.

Essentially, PLF facilitates sustainability goals in the direction of curtailing ecological impact, and input wastes and exploiting economic effectiveness, exploiting food security and livestock wellbeing. Conversely, the burden of high labor costs and the need to keep to growing ecological quality standards has made the European Union (EU) a strong supporter of PLF research (Werkheiser, 2018). It is highly recognized in Europe to meet the swelling universal need/want for livestock protein products, in addition to to overcoming the struggle of economically sustainable ranches in many areas in Europe and the US. This effort allows livestock agriculture to continue as a legitimately and economically viable plan. Outside this intervention like PLF, there would have been a risk of fundamental food production freezing entirely out of Europe (Werkheiser, 2018). Therefore, the potential of PLF preserves husbandry while re-forming a non-natural form of the semi-mythic image of the good stewardship for caring of livestock and making it reasonably eye-catching to sundry in Europe and other areas of world who now value livestock husbandry (Werkheiser, 2018).

Previous studies emphasized on the use of PLF technologies to increase peoples' interests in producing livestock such as cattle, pig, and chickens without having direct human contact with the livestock (V an Hertem et al., 2018; Nasirahmadi et al., 2017; Dawkins et al., 2017). Hence, PLF usage seduces youths to appreciate livestock farming as a means to avert the risk of valuable food (animal proteins) moving out of many countries. However, the awareness of the use of PLF technologies in rearing mammalian mini-livestock such as grasscutter, porcupine, duikers etc have not been established. Achieving the inclusion of PLF technologies in mammalian mini-livestock production would make the business attractive to youths (unemployed graduates) and encourage more availability of animal proteins in global human diets. Therefore, the intention of this paper was to x-ray the dimension's of the surviving PLF technologies that back the judgement of mammalian mini-livestock wellbeing.

The Overview of PLF in Mammalian Mini-Livestock

Conventional way of monitoring mini-livestock within groups is often challenging to animal breeders and even to prospective breeders. The use of PLF technologies become necessary to care for mammalian mini-livestock such as grasscutters, rabbits, porcupines, duikers etc. in captivity. PLF implies using the automated remote system in detecting and monitoring individual animals for health and welfare (weight and state of the body, and genetic metrics) via instantaneous examination of images, sounds, and data tracking (Neethirajan, 2017; Berckmans, 2014). With the help of PLF, the volume for timely exposure of ailment or biological status of the livestock at the farm level can easily be achieved. Therefore, computer science expertise and inexpensive sensors off-labelled from the video gaming industry (Xbox, PlayStationR) combined with the increasing computer size for capturing and handling data have greatly increased the evidence, applications, and accessibility of PLF (Berckmans, 2014). Some of the available PLF technologies across livestock production farms include automated cameras, electronic control of ventilation systems, flow meters, accelerometers, microphones, thermal cameras, photoelectric sensors, radio frequency identification (RFID), automated feeders, automated cleaning systems, biosensors, pedometers, electrodes, olfactory receptors. Several PLF technologies for enhancing husbandry processes are advanced to continuously spot the bodily and behavioral changes of livestock in real time.

Remote Sensors and Livestock Recognition

The integration of far-off checking sensors, the practice of algorithm advancement, and machine erudition is the best way to comprehend how the present technology may affect the world of precision livestock agriculture. Data, for example, images, sounds, hotness or motion from either group or individual livestock are captured or monitored using far-off sensors like cameras, microphones, thermistors and infrared imaging, accelerometers, RFID, optical character recognition, flow meters, thermometers and accelerometers, automated feeders, and automated cleaning systems. Algorithms, therefore, process the information from the sensors kept in external drives and led them straight to a processing node. The processing node is an equivalent of a device that transfers photographs from a digital-camera to a computer. According to Benjamin et al. (2019), algorithms are procedures or systematic sets of operations applied to resolve a definite challenge or clusters of it. To add, programming algorithms communicate a computer exactly what pace to take to resolve a challenge by using inputs to define the outputs

Computer scientists induce the procedure through algorithm script that directs the computer on how to accomplish the exact actions essential to resolve a challenge. Algorithms' worth to breeders is reliant on its skill to convert the sensor records or features variable into a genetic upshot (Benjamin et al., 2019). In mini-livestock production, such feature variables include the fraction of time such livestock lay down to ascertain the genetic upshot (lameness) or the sum of coughs to spot the genetic upshot (breathing disorder).

Machine erudition is a crop of arithmetical systems that permits an algorithm to programme the situation using large circles of instances. Since a computer studies from the sets of current data, it can turn out to be highly proficient at treating and scrutinizing large data sets to track variables and generate estimates at a rate that is impossible for manual statistical approach (Putri, 2015). In summary, statistics from far-off checking sensors is united with individual livestock identification, referenced analyses and production data that is then incorporated into algorithms to offer reliable evidence and alerts concerning livestock wellbeing, health, and yield (Guarino et al., 2017).

The Use of Automated Cameras to Capture Livestock Behavior and Physiology

Automated cameras are systems connected directly to the farmer's computers, tablets or smartphones based on the probes placed under the feeding troughs, which provide useful information about the animals' behavior and physiology for decision-making. The livestock welfare decision-making takes the dimension of their solid and liquid nourishments. This system involves the design of a hypocycloid gear motor with an adaptable tubular space governed and operated by a system of automatically controlled sensors. Cameras detect position and movement in cages through image analysis using either 2D or 3D cameras. Image examination translates the attained images into indices of livestock location, position, and movement (Kashiha et al., 2014). Imaging in mammalian mini-livestock is useful to estimate the livestock weight, hostile behavior, walking patterns, doe position and behavior before parturition. In pig, research on image examination using two-dimensional (2D) cameras offered reliable digital data about effective monitoring and estimation of pig growth rates within 1 kg

(DeBoer et al., 2013; Marchant et al., 1999). On the other hand, 2D camera sensors need satisfactory ambient illumination and contrasting background for better image capturing. In addition, 3D cameras like Microsoft Kinect (Microsoft, Redmond, Washington) and IntelR RealSenseTM (Intel, Portland, Oregon), cameras are furnished with a high-definition camera, an ultraviolet illuminator and a time-of-flight (ToF) depth sensor that produces color (Benjamin et al., 2019). The use of ultraviolet is very important during low lighting to detect the nocturnal behavior of livestock (Kongsro, 2014) and depth sensors are vital to decide the livestock closeness to the camera (Mittek et al., 2017). ToF-depth technology drives a pulse of ultraviolet light from a LED in manifold times in a second, and then registers the delay concerning the pulse and its reappearance to each pixel (Nasirahmadi et al., 2017). This is advantageous when taking the differences of magnitude to create a topological map of livestock for 3D geometry appraisal.

Figure 1. Depth camera sample image containing grasscutters and a porcupine.

The use of Microphones to Detect Sound

Modest microphones translate sounds into electrical signs that are transformed in computers to identify, categorize, and localize precise acoustic actions that include warnings of strain or illness (Schön et al., 2002). For example, a non-acoustic sound in the mini-livestock farm is been linked to stressful or unpleasant situations and cough sounds are often linked to respirational illnesses and hence to their welfare (Opara and Fagbemi, 2009). Coughing is a signal of respiratory glitches in mammalian mini-livestock management that is attributed to either dust, feeds, respiratory tracts infections. Quantifying coughing is a most germane indicator that contributes to livestock wellbeing duty done either at the group or at individual level. Besides, if stress and pain-relatedvocalizations could be unfailingly recognized, they could also be recycled to further the welfare aspects that include stress assessment and fighting activities. Consequently, with the enactment of sensor-technology, microphones and vocalizations would convert a spontaneous daily measure for livestock welfare improvement. A study on sound analysis has yielded good results in detecting coughing pigs (Manteuffel et al., 2017

Using Thermistors and Electromagnetic Imaging to Monitor Body Temperature

Thermistors fixed in a data recorder or ear-tag sensor are used to monitor livestock body temperature using a contact measuring media. The direct contact of sensors with the livestock body takes the degree of temperature and provides its accuracies to $0.1^{\circ}C$ (Sellier et al., 2014). Hence, the use of ultraviolet or electromagnetic technology requires no contact with the animal and still offers reliable far-off measuring. However, the only bodily source of ultraviolet device is such that any object with a temperature above zero (0^{oC}) radiates ultraviolet or infrared emission. Meanwhile, the temperature of such an object defines the wavelength of emission. Therefore, thermal imaging is performed to convert radiant heat into a computer-generated color image. Ultraviolet or infrared cameras, through the non-invasive or instantaneous method, measure physiological and pathological processes that are predictors of variations in body temperature (Sellier et al., 2014; Stewart et al., 2005). The condition by which thermo-regulation increases blood flow to the livestock skin tissue causes complex surface temperature, whereas, outlying temperature evaluations depends on central temperature, ecological circumstances and the outlying blood system regulation (Sellier et al., 2014).

Using Accelerometers for Motion Tracking

Wearable sensors containing accelerometers are hopeful technologies for monitoring mammalian mini-livestock behaviors. Accelerometers are electro-mechanical devices used to determine fast-tracking forces. The movement forces can either be static (livestock lying down) or non-static (livestock walking). The movement, therefore, generates pressure on microscopic crystals *o* stored within *o* the accelerometer *o* and generates electrical energy. The amount of the electrical energy interpreted by the sensors determines the hastiness of the movement and orientation (Benjamin et al., 2019). A tri-axial *o* accelerometer gathers three-dimensional *o* data (x-, *o* y-, and z-axis *o*) that determines the earth's gravitational *o* pull by measuring the angle *o* at which the device (e.g., ear tag, neck collar) is skewed in addition to quantifying acceleration forces.

Using Radio Frequency Identification (RFID) to Manage Livestock

RFID chip is a reliable device for livestock identification for health purposes and management (Brown-Brandl et al., 2017, F örschner et al., 2018). The device is therefore implanted on any part of the livestock's body to store animal information and farm records. Then, communication sets in between the radi o wave (whether at low, high *o* or ultra-high *o* rate) and the transponder *o* circuit inside the tag *o* and an RFID *o* reader to wirelessly *o* read and write facts. Consequently, when an RFID tag gets in contact with the sort of an RFID reader, a signal is received. Moreover, a second radio level signal is stimulated that carries the data to the reader (A rif f et al., 2014). The information are then stored for future analysis or the RFID chips can immediately be used to detect individual livestock.

A low frequency RFID is a valuable component of housing management in mammalian mini-livestock with respect to their feeding and health conditions. RFID is useful in mixture with other devices such as scales and automatic feeders and drinkers. Using such feeders to feed them, the technology collects ID data and frequency of feeding. Irregular appearance of definite livestock might raise an alert to breeders so that health concerns and other unwanted social behaviors could be curtailed early in their emergence (Co nou et al., 2008). The use of Ultra-High Frequency (UHF) readers has been recommended to track numerous livestock at a better range (3 to 10 m) (Sales et al., 2015)

Figure 2: RFID chips on the ear of rabbits

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Using Visual Character Recognition for Tracking Livestock

Ocular character recognition is a low-cost ID system that can recognize printed, marked, or written text characters (barcodes, QR codes) by a computer. In mammalian mini-livestock (grasscutters, rabbits, duikers, porcupines, etc.) husbandry, ocular recognition includes such fonts on their ears or as painted signs and numerals on their bodies. Visual/ocular character recognition is achieved with a digital camera and data is established with machine erudition to offer far-off identification. In macro-livestock, studies indicated ocular character recognition can identify large permutations of animals irrespective of any identification marks used (Lancaster et al., 2 012; Mittek et al., 2 016; Mittek et al., 2017).

Figure 3. Tinted figures and ear tag for ocular character recognition on a rabbit.

The use of Flow Meters to Measure the Drinking Pattern of Livestock

The application of flow meters is necessary for mammalian mini-livestock stalls to assess their daily drinking patterns and water usage. The adoption of this technology has the potential to predict an outbreak of disease or the emergence of vices due to biting. A study revealed the efficacy of using flow meters to predict numerous wellbeing conditions that include incidence of disease (Kim et al., 2017), and tail biting outbreaks in pigs (Schaefer et al., 2012). Another study on the performance of caution algorithm based on aberrations from a likely diurnal pattern in water ingesting indicated that the algorithms were efficient in predicting an incidence of diarrhea epidemic one day before the presence of medical signs (Kim et al., 2017).

The use of Thermal Cameras to Measure Body Temperature Variations

Regular measuring of body temperature is key in relation to maintaining livestock welfare as below or above a certain threshold may cause the livestock severe performance damages. Therefore, thermal cameras are the most used remote technology to detect livestock body temperature (Neethirajan, 2017). In addition, physiological responses due to inflammation from lameness can effectively be monitored using thermal cameras. Thermal imaging differentiates lame from non-lame livestock and detects temperature changes in the affected body part. Therefore, the welfare difficult occasioned by pain from the inflammations related to lameness can be spotted by thermal imaging. A thermal imaging study on cows indicated that thermal cameras are promising tools for observing physiological responses due to swelling/soreness related to lameness (Adams-Progar et al., 2017).

Use of Automated Feeders

Since feeding is the greatest and expensive consideration in livestock husbandry, it should be prudently attuned to fulfill livestock' energetic necessities during their lifespan instead of embarking on over-feeding and consequent waste of nutrients. To ensure the livestock feed correctly to meet certain nutritional requirements and maintain proper health, installation of automated feeders play a focal role in ascertaining and sustaining the animal's health and comfort (Gellings, 2021). This is necessary to avoid waste while feeding mammalian mini-livestock as they spend about 13 hours per day resting or sleeping, 6-7 hours eating, about 2 hours training themselves, and the remaining time playing (Nyameasem, 2018). With automated feeder systems, farmers can then provide the livestock with feeding mixtures and amounts tailored specially to that livestock' needs. Feed checking technologies help breeders to detect how much additional feed will be needed based on what is available in their stock.

Automated Cleaning Systems

These systems help to automatically remove wastes and runoffs from mini-livestock enclosures and move all to a heap that can then be easily moved using machinery (Gellings, 2021). This technology is new and very beneficial in removing waste automatically which helps decrease illness and forms a cleaner environment for the livestock. Also, the application of this technology limits the frequency of farmers' interaction with livestock wastes, a reason why many hate rearing livestock. Hence, more youths would be seductively drawn into the business of livestock production as little or no interaction is needed in the waste management duty. Other PLF technologies and their uses include biosensors for detecting pathogens in the air or in the stool, Pedometers for predicting estrus, electrodes for detecting skin conductivity and heart rate, and olfactory receptors for detecting illness (Werkheiser, 2018).

The use of Mobile Applications, Wi-Fi, and Bluetooth

Presently, the trend of mobile application utilization such as smartphones and tablets is useful to display encrypted data collected from various farm sites through Wi-Fi or Bluetooth. Prior to this, sensors are placed in isolation, therefore, collect encrypted data from different spots inside the ranch system, gathered it, and send it to a resident computational system (node or base station) for processing to filter unnecessary information (Smith et al., 2015). PLF devices require stable internet connectivity, however, the current networking infrastructure limits their usefulness within farm industries. As a result, many farms in rural areas find it difficult to access mobile services and Wi-Fi due to inadequate supply and insufficient network availability for the installed technologies (Smith et al., 2015).

Assessment Summary of Hardware and Software

Table 1 below holistically summaries possible characteristics and fallbacks of various sensor devices with their particular examples and uses.

Table 1. A contrast among sensors and their uses

PLF Hardware Assessments			
Sensor device(s) and Producer examples	Characteristics	Fallbacks	Uses
1. Cameras : 2D (RGB)	▪ Useful for fine positional	▪ Requires filtering to obtain	▪ Optical character recognition ▪ Feature extraction

▪ Lorax ▪ eYenamic® 3D (RGBD)® ▪ Microsoft Kinect® ▪ Intel Realsense® ▪ eYegrow®	▪ and color variational data ▪ High precision and lots of facts ▪ Remote sensing (non-invasive) ▪ Fast readings (usually 15–60fps) ▪ Individual or group can be analyzed	▪ useful information ▪ Performance is dependent ▪ on lighting conditions ▪ May require protective ▪ covers against environmental elements	▪ Motion detection ▪ Topology extraction ▪ Animal distribution and activity
2. Thermometers ▪ Infrared Imaging® ▪ FLIR® ▪ FLUKE® ▪ TESTO 875®	▪ for biological process ▪ scrutiny and night vision ▪ High performance in low ▪ visibility settings ▪ Remote sensing (non-invasive) ▪ Fast readings (usually 15–60fps)	▪ Expensive (Mid hundreds to several thousand per unit) ▪ Environmental factors affect readings	▪ Remote temperature sensing ▪ Low light imaging ▪ Physiological responses (individualized and group)
3. Thermistors • Integrated in wearable sensors	▪ Useful for temperature fluctuations ▪ Inexpensive	▪ Slow to sense changes ▪ Not an off the shelf system	▪ Contact temperature sensing ▪ Physiological responses
4. Microphones • Soundtalks® • PCM Monitor®	▪ Useful for sound/frequency fluctuations ▪ Immediate readings ▪ Inexpensive	▪ Easily corrupted by noise	▪ Monitoring periodic physiological process (in pens and/or barns) ▪ Auditory classification
5. Accelerometers Examples of WSN • Remote Insights® • Smartbow®	▪ Useful for motion tracking ▪ Near instantaneous readings ▪ Embedded into wearable sensors used in wireless sensor networks (WSN)	▪ Requires external processing to obtain displacement and velocity data ▪ Information is relative ▪ (Not complete) ▪ Delicate (can break with livestock behavior)	▪ Motion detection/observation (i.e., walking, nesting behavior) ▪ Positional state tracking (i.e., lying, standing)

Welfare/Health Challenges in Mammalian Mini-Livestock Production

Generally, consumers expect that all animal-based foods to be produced must first observe and respect the animal welfare requirements. Consequently, a digit of ethics and agencies have been set in place to guarantee the municipal that all livestock receives appropriate treatments (Ve issier et al., 2008).

Therefore, animal based measures are in place in the livestock industry to make the inspection of livestock possible at all stages of production (Pairis-Garcia, 2016). The subsequent section focuses on the aim of the study that included an over-all account of individual and group mammalian mini-livestock health challenges that include lameness, body condition, livestock well-being, hostile activities, and identification of an ailment

Lameness

Lameness is that condition of obstruction to the posture of livestock. it is a scientific sign that is linked to a kind of disorders such as claw lesions, trauma, osteochondrosis, fractures, skin lesions, and inflammation (Adri, 2014). These disorders are parameters of critical failure criteria and are most common within a group when breeders ignore the required management practices that result in economic losses in commercial production (Salihu & Abdulrahman, 2020; Adri, 2014). Furthermore, the connection between lameness and pain reduces optimal welfare in mini-livestock. Solicitation of unbiased practices to evaluate lameness steadily on farms and recognize slightly and judiciously lame populations of mini-livestock would improve the livestock welfare before the condition of severe lameness sets in.

Body Condition

Body condition scoring *o* (BCS) is the bodily appraisal of animal body conformation to assess the quality of nutrition given to the animal (Courboulay et al., 2007). Therefore, mammalian mini-livestock with low BCS becomes emaciated and less active with the presence of sores in their teeth (Salihu & Abdulrahman, 2020; Adri, 2014). Therefore, thin mini-livestock assessed by body weight *o* and low back-fat *o* depth *o* are better culled from the group. There is a specific value in salvaging foretelling pointers of body disorder due to the connections with lameness and teeth abscesses. Studies in dairy cattle suggested progressive associations concerning *o* low body *o* condition *o* and *o* lameness, where cattle with BCS <2 were at utmost danger of lameness, and cows that suffer a greater decrease in BCS, had a greater likelihood of becoming lame and a lower likelihood of improving in the next 15 days (Randall et al., 2015). Survey information presented that sows removed from *o* the breeding *o* flock for BCS *o* and lameness *o* had fewer back fat.

Welfare at the Level of Colony/Group

At the level of colony, ill and injured livestock signify a helpless group with exclusive needs and preferences (Millman, 2007). The breeders are therefore expected to adopt livestock-based measures that include every day observations to monitor the livestock' well-being and spot irregular activities or scientific signs of malady and wound or pain. Most of the behaviouurs that show mammalian mini-livestock are sick include shivering, clustering and inactiveness, variations in social interface, decreased ingesting and drinking, a lump under the skin, diarrhoea, coughing and nasal discharge, worn-out fur, and death of suckling pups (Salihu & Abdulrahman, 2020; Adri, 2014). Assessment of mammalian mini-livestock without human presence assists in observing their existing health conditions for quick attention. The incidence of symptoms of sickness in a flock is associated with a damped environment, un-disinfected cages, the presence of dust, and failure to offer antibiotics.

Monitoring and controlling pointers of illness might develop individual livestock welfare and animal-based measure outcomes. Whereas sound detection *o* in case of a recurrent symptom of breathing ailment among a group might be used to demonstrate treatment regimens and decrease individual mini-livestock disease.

Prolapse Disorder

The incidence of prolapse syndrome is common among mini-livestock where the livestock find it difficult to walk or lie down due to protrusions found in the body parts (Salihu & Abdulrahman, 2020; Adri, 2014). The does suffer from either uterine, vaginal, or rectal prolapses and the bucks suffer from scrotal or testicle prolapse during their productive ages. A uterine *o* or vaginal prolapse *o* upshot in both does death and loss of unborn *o* pups. Welfare requirements such as immediate euthanasia of the livestock are essential to relieve pains and worries to the animal keeper. The breeder(s) easily identifies organ protrusions during direct contact. However, the process is risky and therefore there is a reasonable assumption that using machines, with enough imaging, causal variables such as does' morphological or posture characteristics can be detected with ease.

Description of Distant Monitoring Technology Applications for Mammalian Mini-Livestock

This section focuses on a general explanation of group mini-livestock welfare tasks that include lameness, body disorder, prolapse, comfort, hostile behavior, identification of disease, and resultant research and distant checking applications within PLF.

Lameness and Movement

Predictably, lame mini-livestock act inversely owing to bodily abridged movement, body pain or over-all uneasiness, and illness behavior (Salihu & Abdulrahman, 2020; Adri, 2014). In groups, mini-livestock with un-resolved lameness conditions move and stand less, lie down often, and are in contact with the cage wall more than healthily controlled ones. These behavioral changes could be interpreted as signs of discomfort or as a way of looking for shelter and isolation from the group. Unfortunately, with some personnel managing this livestock, lameness is frequently unnoticed until it is moderate to severe.

The automatic techniques that can mark lameness comprise pressure mats or *o* force-plate *o* systems, *o* imaging, and *o* accelerometers. *o* Force-plates are effective to determine the pressure *o* distribution of *o* claws, weight distribution *o* on the legs of livestock, leg *o* loading, and *o* weight instable. Studies showed effective uses of force plate technologies in identifying anomalous or asymmetric *o* gates in lame *o* pigs (Meijer et al., *o* 20*o*14; Sun et al., 20*o*11; de Carvalho *o* et al., 2009). Force plates like the GaitFourR, is an automated pressure *o* mat and software that assess lameness via measures comprising extreme pressure, stride *o* length, stance *o* time, stride time, and activated *o* sensor count per foot *o* (Karriker et al., 2013). The incorporation of a pressure mat or force plate in mammalian mini-livestock production would provide referenced standards for measuring lameness despite its complex installation systems.

Other variables of lameness in mammalian mini-livestock include reduced walking speed, irregular *o* strides, and swayingo from beginning to end. The visual characteristics can be spotted via motion tracing and topologicalo examination. With reference to the realization of image examination in dairyo cattle to forecast lameness (Van Hertem et al., 2018; Van Hertem et al., 2014), it is likely that an objective lameness detection system using imaging will be developed for mammalian mini-livestock. In this case, motion tracking between frames from consecutive images of a video would offer a calculated lateral motion path to be compared with the actual forward movement of each livestock.

Researcho on the efficacyo of the use of accelerometers attached to the leg of livestock to detect postureo and stepping behavioro, standing duration, expectancy to lie downo after feeding, and frequencyo of step when feedingo, nesting activity, and the onset of farrowing has been established (Traulsen et al., 2016; Conteo et al., 20*o*14; Grégoire et al., 20*o*13; Ringgenberg et al., 2010). Therefore, the livestock has to be plugged into fitted devices elsewhere and data sampled from ear tags. Applying ear tag accelerometers to livestock, a prediction of lameness and other variables such as high activity (distance walked) and rest phases (lying down) would be compared easily since the ear is the most decoupled body part of the locomotory system. Applying ear tag accelerometers in mammalian mini-livestock, postureso and activity nest-building behavior can be monitored to predict parturition time, and detect lameness based on does or buck postures that could generate early alerts of disease. A study by Marcon et al. (2017) showed high accuracy in the use of ear tag accelerometers to spot static behavior such as the time that an animal spends lying. However, a lower accuracy was established on other livestock behaviors such as time spent standing and time walking.

Cage Level Activity Monitoring

The applications to improve wellbeing and automate mammalian mini-livestock monitoring take in video images to measure cage-level activities that include hostile behaviors, chasing, flank biting, fighting, and trunk scratching (Ott et al., 2014; Kashiha et al., 2013). Sensored data distinguishes the lying patterns of this livestock (thermal ease/comfort behavior) and unmoving from the moving ones. Depth image tracking spots livestock location, eating, drinking, and aggressive interfaces between mammalian mini-livestock within a colony. In this direction, a study by Mittek et al. (2016) and Lancaster (2018) showed significant results of depth image tracking in pigs. Another method to cage monitoring is the use of 3Do cameras and machineo learning to spot mammalian mini-livestock action and offer an automatic warning of hostile behaviors, chasing, flank biting, fighting, and trunk scratching outbreaks.

Electromagnetic Thermography

Electromagnetic thermography is a means to non-invasively spot the dissipation of heat in individual livestock or specific parts of the body for rapidly detecting illnesses, inflammation, locomotion disorders, and respiratory disease in livestock production. Introducing electromagnetic thermography in mammalian mini-livestock farms would guarantee early detection of diseases, locomotion disorders, and respiratory disorders. Studies have established the use of electromagnetic thermography in pigs to detect such health challenges through their skin measurement sites (ear base, eyes, and udder) (Harris-Bridgeo et al., 2018; Alsaaod et al., 2014; Schaefer et al., 2012). Electromagnetic thermography can be used to detect individual illnesses in groups of pups or weaned pups.

Sound Detection

Sound recordings with an algorithm is used for vocal examination to detect heat stress and high incidence of shrieks of pain due to fracture and/ or dislocations. Algorithms also distinguish between infectious and non-infectious productive cough. Non-productive coughs (ammonia or dust) are noticeable from variances in the acoustic variables. The use of sound recording with an algorithm has been effective in detecting coughing pigs (Ferrari et al., 2013; Ferrari et al., 2008; Exadaktylos et al., 2008). SoundtalksR (Leuven, Belgium), a commercially available sound detection package, identifies sounds in a confined area and enables treatment for respiratory disease and changes in ventilation at cage level. Sound detection is hindered if the cage becomes noisy or microphones are deficient. Breeders being able to steadily differentiate stress-related and normal vocalizations would be helpful, as mammalian mini-livestock would speako for themselveso about their wellbeing.

Livestock Physiology, Live weight and Body Condition

The vital factors in the management of mammalian mini-livestock are the live weight, shape, growth, and body composition because individual livestock weight and growth affect the colony cage flow and space allowance as well as audit parameters (Salihu & Abdulrahman, 2020; Adri, 2014). An animal-based measure of mass allowance indicated that one buck to four does are kept in a colony cage while a maternity cage should be one doe to an individual cage (Salihu & Abdulrahman, 2020; Addo, 2002). The use of 3Do cameras is appropriate to extract the 3D shape of the livestock for spontaneous mass and weight estimations.

Wireless Sensor Networks

The wireless sensor networks (WSNs) consist of sensors, nodes, and base stations (Figure 4). Usually, low cost and low power, multifunctional sensors such as a thermistor, accelerometer, and battery are clustered in one node. For mini-livestock production, the sensors (accelerometers) are compressed within an ear tag (node) which holds the sensor package for message. The node directs data to the base station that provides connectivity to the server in order to implement computational tasks (Molapo et al., 2019).

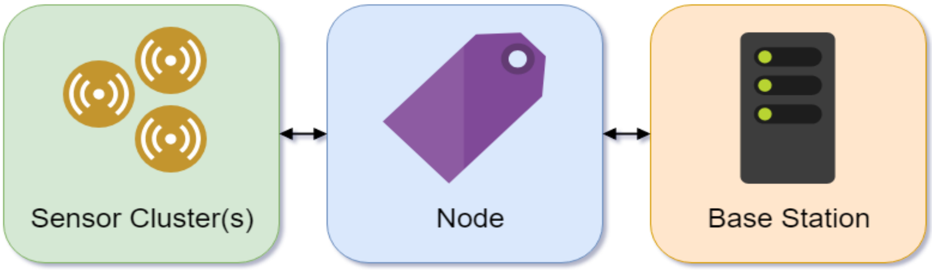

Figure 4. Wireless sensor system edifice

WSN is a commercial remote insight Wireless Asset Management System (Remote Insights, Minneapolis, MN). Agreeing to the patent, accelerometer and fever device sensors housed in the node are wrapped to inhibit the entry of vapor or dust. The ear tag node (beacon) transfers its distinctive ID to an entry or base station via cellular, satellite, Wi-Fi, or internet and conveys instant optical message to the breeder using diodes that release alarms or behavior arrays such as movement disorders (Cairns et al., 2016).

Implication of Precision Livestock Farmingo for Breeder and Veterinarians

A successful mammalian min-livestock farmer is one who resolves health challenges, generates prospects, and promotes the financial achievement of their customers. Empowering mini-livestock farmers in disease management practices is key and needs to be promoted to spark the value of the livestock management software and analytic programs to offer key production indices for mini-livestock production that include mortality, productivity, market weights, and feed conversion of the livestock within the colonies. Other data records to be delivered by the farms take in parturition/kindling data (e.g., kindling dates, number of pulps born) and diagnostic data (e.g., reasons for injuries, reaction to treatment, reasons for death) (Smith et al., 2015).

On the other hand, sensors digitize physiological variables are indispensable, where the livestock are monitored frequently so that predictive data are generated for accurate prescriptions (Shepherd et al., 2018). The data is therefore utilized to predict tendencies and behavioral patternso that would supporto a decision-makingo process that is devoid of evidence bias (Halachmi et al., 2016; Smith et al., 2015). Thus, mini-livestock wellbeing can be enhanced if farmers/breeders can precisely assess the economic results of easing practices.

A Practical Role of Mammalian Mini-livestock Breeders

Livestock welfare is a moral carter with economic values and a financial driver that carries an honorable weight (Dawkins et al., 2017). The most plausible way in which welfare and financial productivity form an association is through the decline in mortality and morbidity in livestock. Calling or timely euthanasia of severely injured or lammed animals or animals with uterine prolapse with poor prognosis are such humane acts to meet livestock welfare. Most of these welfare challenges are attributed to the livestock phenotype, cage activity, physiological comportment/posture and timely discovery could develop both profits and wellbeing.

Therefore, farmers are expected to determine the prevalent disease, risk factors, and the worth of analytic outcomes within the farm schemes (Millman, 2007). Furthermore, mammalian mini-livestock farmers through their preparation and manifold on-farm visits must be able to identify normal from anomalous physiology and risk factors for poor wellbeing of the livestock. The goal of PLF technology is to offer detection and consequently timely indicators of glitches that classify individual livestock or specific groups that needed care. Mammalian mini-livestock farmers and their customers are self-assured that the technologies are both exceedingly subtle and precise to guarantee detection and shun needless alerts (Halachmi et al., 2019; Arcidiacono et al., 2017), and veterinarians could support engineers and programmers in planning on the exact observations that are founded on biological consequence and proof (Norton et al., 2017).

Opportunities in PLF Applications

All the PLF technologies mentioned in this paper could advance into profitmaking products that can advance earnings for livestock farmers/breeders (Berckmans, 2014). Hence, livestock breeders adopting the PLF will need inputs from right-hand partners to spread and offer knowledge and guidance on enterprise and proprietary dealings with sensor designers to guarantee investor traceability.

Workforce development is an industrial opportunity in which application of PLF offers. That is, an automated and objective technique to observe and collect data can streamline labor needs, decrease the inadequacies of routine responsibilities, save time and invite diverse type of stock persons. PLF changes the manner we work and allocates resources (time and energy) to the advancement of foretelling treatment management and procedures. Hence, rapid intervention, in the case of disease outbreaks or changes in the livestock stress management strategy would become easy to improve the livestock status using PLF technologies. Furthermore, the application of PLF technologies improves livestock wellbeing. A non-invasiveo or automated systemo improves mini-livestock wellbeing and attention through individual livestock approaches. Real-time outcomes are provided since they are techniques convert farms to research facilities. For example, an automated system of PLF can measure livestock aggressiveness as it monitors real-time animal health and welfare continuously.

Automation of livestock husbandry increases ethical concerns about machine learning substituting human attention (Werkheiser, 2018). Based on individual or per livestock approach, others maintain that the automation system improves association between breeders and the livestock (Halachmi et al., 2016). The only drawback is the fact that it is not at all times clear what information should be obtained and why it is pertinent. Therefore, breeders should collaborate with PLF engineers and technology designers to fashion productso suitable for on-farm use that would impact positively on the wellbeing of the livestock.

CONCLUSIONS

The world expects a surge in human population to about 9.7 billion by 2050, which calls for intensification of efforts to meet the World Bank predictions of upsurges in demand for meat that must be unrelenting by 90% of current farmland (Röös et al., 2017). Facing the stresses of collecting and analyzing numerous data about livestock which no human being would accomplish within the shortest time, the application of PLF can provide mammalian mini-livestock breeders with information about the welfare of livestock. Expanding PLF and the possibilities for interconnection in the mini-livestock value chain ultimately links customers and farmers. Consumers will make decisions based on farm practices, and farmers can make decisions based on consumer practices (Shepherd et al., 2018). The role of the mini-livestock breeders can be anywhere in association with assisting to navigate PLF toward prosperity for all. In light of this, more farmers including the unemployed youths would become interested in producing more livestock using PLF technologies instead of the conventional ways that are disinteresting.

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