An Integrated Model to Facilitate and Increase Productivity in the Production of Heavy Livestock

Arjmand,P. [1*]; Noshad, A. [2]; masoodi,R. [2]
[1]Department of Information Technology , Faculty of Engineering, Salman Farsi University of Kazerun , Kazerun, Iran;
[2]Student of Computer Engineering, Salman Farsi University of Kazerun, Kazerun, Iran.

*** Corresponding Author:** P. Arjmand, Department of Information Technology , Faculty of Engineering, Salman Farsi University of Kazerun , Kazerun, Iran, *Email :Arjomand@kazerunsfu.ac.ir*

(Received: July 10, 2020; Accepted: October 20,2020)

Abstract

With less or no knowledge regarding animal health, nutrition, production process, and reproduction procedures, and without a scientific plan and program achieving a desired economic profit is absolutely impossible. There are many parameters involved in recent animal husbandry investigations, which determine the conditions and present vital information about the health of animal. Collecting this information enables the rancher to do the right thing when needed. Collecting and analyzing data can be a challenging task. Therefore, developing a monitoring system able to collect and analyze data automatically can be very useful. This article investigates the development of a livestock farming system for horses using nutritional parameters, body temperature, activity level and horse chewing. Collecting and evaluating data using livestock farming system may help the breeders to determine its effects on horse husbandry.

Key word: *farming system, livestock, data mining, local process, data base*

Introduction

Nowadays, without knowledge of animal health, nutrition, production and reproduction status scientific planning and achieving the desired economic interval would not be possible. Accurate recording of livestock status help plan the best for breeding, hygiene, nutrition, under normal circumstances, as well as to make the best decision in abnormal and critical conditions. To fulfill this purpose, it seems necessary to keep a birth certificate in order to maintain the relevant records and to provide the application with information as a database, to make the best use of them. The purpose of registering livestock characteristics is to document any activity and procedure for later use. Any type of livestock breeding activity is possible by identification, separation and recognition of any individual animal in the herd. The birth certificate specifies the condition of the livestock in terms of keeping or removing it from the herd. Also it will better specify the livestock in terms of breeding, nutrition and health, as well as better planning for more production and increase in the economic value of livestock. For example, examining the physiological factors of cattle is used to predict nutrient overload and its function (Fox and Black, 1984). Recording is one of the most important duties of a rancher which helps to economize breeding the livestock provided it is done carefully and accurately. Access to such information and records is of a great help and importance in choosing better livestock, their health, and optimizing the nutrition, especially in bigger livestock. The advances in the technology of the sensors provide the ranchers with more information regarding monitoring animals, and the environment which can increase the livestock's

[DOR: 20.1001.1.2717378.2020.3.6.3.7]

production, growth and health. There are systems available for animal identification and weighing to be used in managing the livestock's information to monitor their physiological information such as body temperature, and heartbeat rate. The use of integrated monitoring systems, where information is obtained from sensors, database, mathematical models and knowledge bases, provides the maximum potential for combining and interpreting the information. For a given group of livestock, product quality depends almost entirely on skill, experience, and mental evaluation of the producer, which depends on monitoring and controlling the production process. Very little technology is currently available that enables the producer to monitor and control variables that determine the value of livestock (Frost *etal*., 1997). The purpose of this article is to review the establishment a livestock monitoring and control system that optimizes the health and nutrition condition and accounts for factors affecting the maintenance and production of livestock which eventually has a significant impact on the rancher's economy.

Numerous research have been carried out on the development of various livestock production systems, including some elements of livestock farming system, one of which was carried out by Dijkhuizen and huirne (1990) for breeding a pig. This system investigated farm data, which included variables such as feed rate, size and mortality. In another research done by Ordolff (1989), on the measurement of milk in dairy cows, since dairy cattle are valuable animals and the amount of milk produced by cows has always been a key element of data, the designing of the milk measurement system attracted a lot of attention (Ordoff, 1989). The DAISY Dairy Information System was developed by Esselemont in 1990 with the help of information retention such as cattle identity, health, fertility, milk quality and cow weigh (Esslemont *etal*.,1990). There are samples of developing systems that have more elements of integrated surveillance systems. For example, Hogewerf in 1992 described a system that monitored the health and production of dairy cows whose system inputs included milk production, milk temperature, cow activity and concentrate use (Hogewerf *etal*., 1992). These parameters provide useful information after each milking. In the research done on the daily monitoring of pigs, valuable information was provided on the path of growth, health and good production for the breeders (Korthals,2001; Lokhorst and Lamaker, 1996; Schofield *etal*., 1999). Other farming systems have been developed so that they can automatically capture animal weight using image processing technology (Kollis *etal*., 2007). Animal weight information can be used with computer simulation models such as AUSPIG to calculate the daily ration. In addition, image analysis can be used to assess pig behavior and well-being (Shao and Xin, 2008; Xin and Shao, 2002; Hemsworth *etal*., 1995). In other cases, factors such as water consumption, temperature and body weight can be effective in identifying the disease (Pedersen and Madsen, 2001; Mottram, 1997). Disease monitoring as well as animal tracking can be significantly

[DOR: 20.1001.1.2717378.2020.3.6.3.7]

linked to electronic animal identification tools and farming equipment (Jansen and Eradus, 1999; Street, 1979; Schon and Meiering, 1987). Therefore, careful monitoring of these factors will have a huge impact on production.

Materials and Methods

Development of livestock farming system

Important processes in livestock farming

The first step in developing livestock farming is to specify important processes that, if done correctly, will have a huge impact on producer's production and profitability. Critical point control is the last place in the process where risk can be avoided and the product quality, production level, profitability and sustainability of the product be maximized and maintained. The most important reason for identifying critical point control in any process is identifying the variables that need to be measured, and the frequency needed to avoid the risk. The most important aspect in developing critical point control is identifying and making sure that only a small number of processes or tasks have a significant impact on production, profitability and sustainability of the product. These processes are referred to as "to be done" processes that can have a significant impact on the success of the producer if not done correctly (Banhazi and Black, 2009). The purpose of surveillance system is to reduce the number of tasks that the producer has to perform and to ensure that these tasks are performed correctly. Important tasks are usually based on their relationships to identifying profits that will have a significant impact on profitability in case these important tasks are not performed correctly. One of its methods of identification is the important task of formal analysis of previously stored data (Banhazi and Black, 2009). This provides a good opportunity to change a producer's profitability, to reduce the costs and unnecessary works, and to increase the reliable ones.

Data collection system

After identifying important processes, the next step is to identify the variables in which the process should be measured. Also, determining the range of variables will affect the accuracy of the process execution (Banhazi and Black, 2009). In the past, collecting data was very difficult and costly. The design of a data collection system enables the producer to access efficient management data (Schon and Meiering, 1987). The farm data collection system can transfer livestock activities, worker, and other farm information to the database where information on operation, storage, processing and transmission to the control system can be done (Banhazi and Black, 2009). Animal weight is one of the most important parameters needed in animal farms. For example, daily monitoring of the growth rate parameter of pigs provides valuable information on the health, growth, etc (Korthals, 2001). Animal weight information can be obtained by computer simulation

[DOR: 20.1001.1.2717378.2020.3.6.3.7]

models such as AUSPIG to calculate the daily diet of pigs to achieve proper growth based on genes and environmental factors (Hemsworth *etal*., 1995; Xin and Shao, 2002). Therefore , if a reduction strategy is used in the field, careful and low cost monitoring of these features is essential(Banhazi and Black, 2009; Korthals, 2001).

Data Analysis system

Computer models in the future will compromise an important part of livestock farming systems (Banhazi and Black, 2009). For example, limiting factors of food consumption and excessive waste of food can be predicted and identified. Diets can be automatically modified at specific times in order to achieve the economically needed nutrients and feed intake for achieving maximum economic efficiency in this parameter (Bird *etal*., 2001). There are different methods used today to analyze data from simple charts and spreadsheets to sophisticated statistical analyses and computer simulation models (Aerts *etal*., 2001; Bird *etal*., 2001; Stafford, 2000). Although simpler techniques may be useful in understanding the inefficiency of production, they are often limited and do not calculate important interactions between factors that affect livestock performance and producer profitability (Banhazi and Black, 2009). Using models that include all sources of production, such as the AUSPIG (Black *etal*., 2001) model, can help identify inefficiencies in production methods and relative profits.

Control system

Any identified process that has a significant impact on farm profitability must operate within the ideal range. Keeping the processes within the ideal range can ensure the profitability of the farm. As a result, when these critical processes fall out of desired range, the system automatically alerts managers or responsible staffs to solve this problem to ensure that key processes are within critical range. Livestock control systems are generally based on computer technologies that require operators. Therefore, SOPs are essential for individual tasks., SOPs ensure that processes are performed correctly and must include all measured variables in their maximum and minimum ranges .When the variables are out of the range there are methods to perform predefined corrective actions. There are two level of SOP: high and low. At the high levels of the SOPs, each of the tasks is important and it is specified when the tasks are performed while low level of SOPs describes how to perform a task or how to work on specific pieces of equipment or software designed to assist in data collection, data analysis and data control. Developing SOPs for a product over current knowledge can be a challenging task, but it seems essential to accept the suggested plan. In addition, having predefined SOPs ensure that whenever the measurement constraints are violated,

[DOR: 20.1001.1.2717378.2020.3.6.3.7]

the level of stress is significantly reduced for producers because these corrective plans and actions are predetermined at this time (Bird *etal*., 2001).

Results and Discussion

The concept of livestock farming system operation

In a livestock farming system, the information is processed using the information collecting sources, and the output may be recommendations to the producer or proceedings to control livestock directly. Figure 1 shows the general concept of livestock farming system that can be used in livestock production process. The inputs of these types of systems include information that the producer imports or is automatically collected by sensors. This information can include weather conditions, food consumption, growth rate, and reproductive status for example, so that the information contained in the database can be checked for quality and status of the livestock. This information is in databases that can be processed and used by analytical models to predict future conditions, and the results obtained from processing can be in different fields such as environmental control, food control, health control, and animal fertility. Finally, the system provides the user with reports and recommendations for taking steps to improve the production process and increase status.

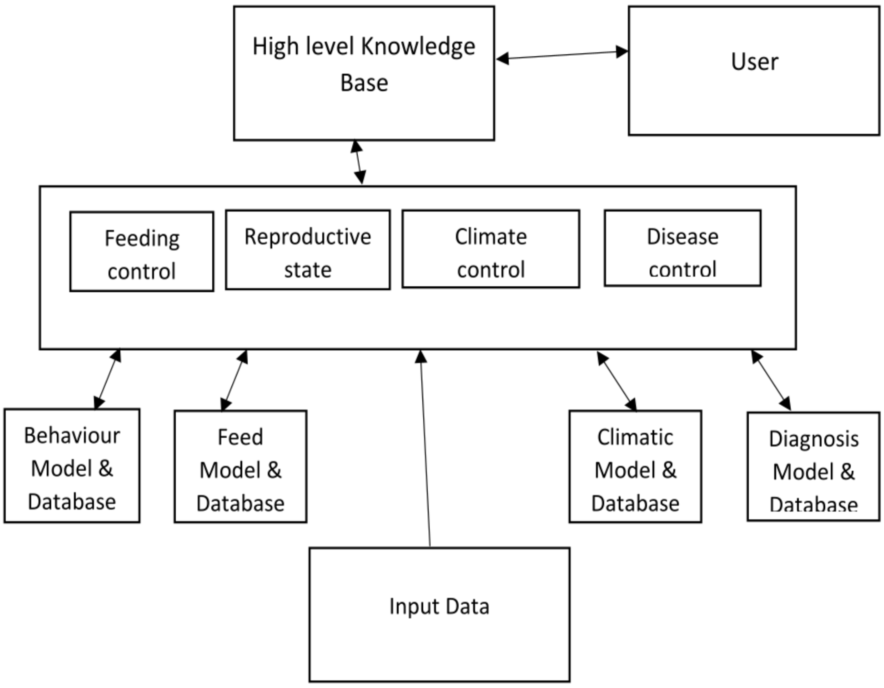

Figure 1. The concept of livestock farming for producing livestock**.**

[DOR: 20.1001.1.2717378.2020.3.6.3.7]

The importance of using the livestock farming system

For successful use of a precision livestock farming system (PLF), we need to provide all the tools needed to measure, interpret, and execute profitable operations. These tools are needed for a livestock farming system and are available for the rancher. These tools may include physical instruments such as a meter to measure height or mass, thermometer, psychometer etc., or it may include descriptive information on how to measure, information tables, charts, spreadsheets, or other types such as software or web links to specific programs. The process of identifying these tools has proven to be an excellent framework for critical research and development projects to ensure that the livestock farming system is fully implemented. An essential component of the system is that all information is easily available to the manager or rancher. One of the reasons for relatively slow adoption rate of PLF technologies in farms is the fact that components of these systems are often developed independently by different research groups without considering the importance of integrating these technologies into a fully functional package (Banhazi, 2006; Dunn *etal*., 2007).

Parameters investigated in the development of livestock farming system for keeping and breeding horse

Chewing activity can be a good parameter for assessing horse health and well-being (Janis, 1976). Measuring the chewing activity automatically is of outmost importance. Based on the research, Rumi Watch System can be used to monitor the activity of horses. Comparison of the data collected by this system automatically and the data collected by visual observation showed a good agreement of 93% between visual and automatic observation. Figure 2 denotes that sensors detect more chewing than visual observation(Werner *etal*., 2016).

[DOR: 20.1001.1.2717378.2020.3.6.3.7]

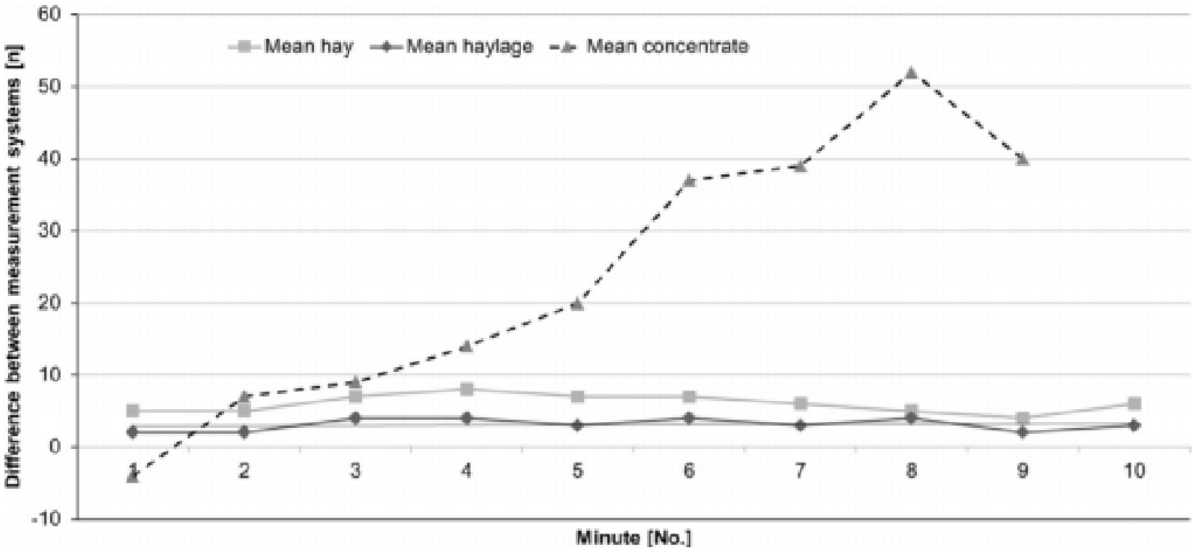

Figure 2. differences between visual observation and automatic measurement of chewing per minute when feeding different food. Positive values are due to greater amount of chewing in the automatic measurement and this is only a sign of a process (Werner *etal*., 2016).

Another useful parameter for assessing the physiological status is the body temperature. CBT is a comprehensive indicator of horse health and physiology and is used to predict the start of a problem. However, more reliable documentation on horse CBT measurements is needed. The ability to control this parameter continuously and remotely will be useful for evaluating the condition of horses in transport. Ongoing monitoring can provide transient and dynamic changes in CBT that may not be detectable during intermittent monitoring and provide a clearer picture of the mobility of physiological reaction (Mitchell *etal*., 2001; Brown-Brandl etal., 2003; Green *etal*., 2008). Studies have shown that a remote monitoring system can be used to continuously measure temperature . Figure 3 shows the information collected by this system.

[DOR: 20.1001.1.2717378.2020.3.6.3.7]

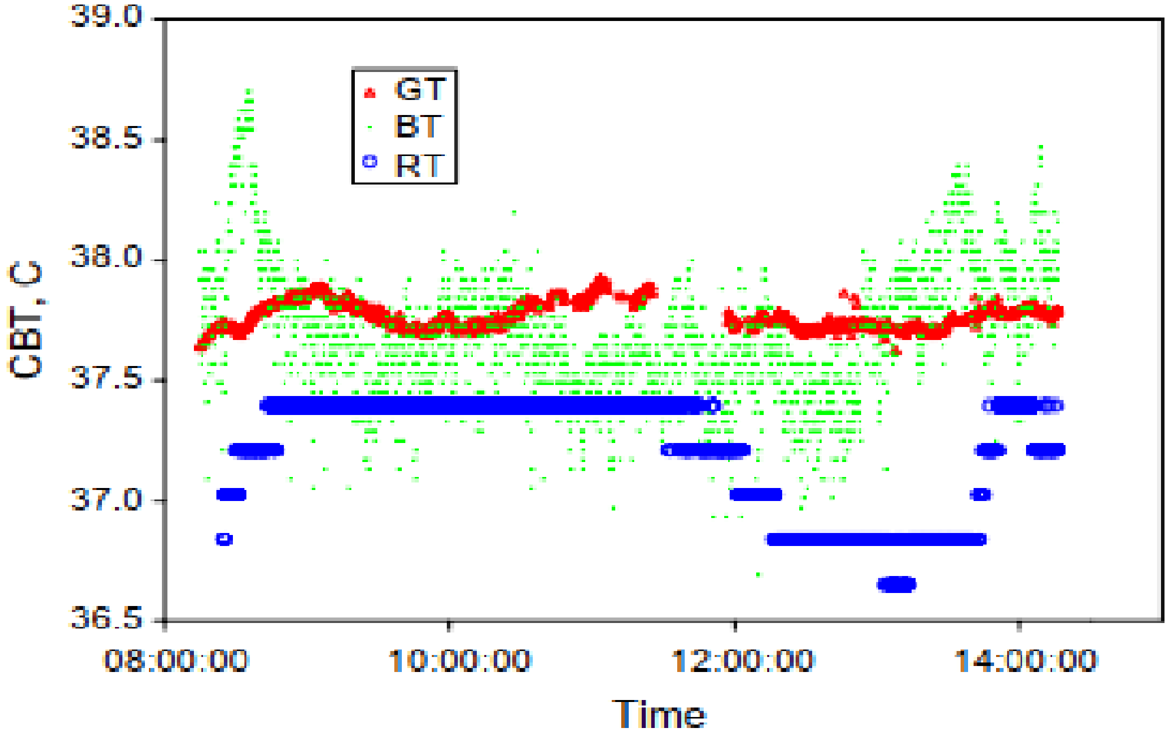

Figure 3. An example of the horse's body temperature in 3 different places (Green *etal*., 2005).

Today, horses are kept individually or in groups. Generally, 84% of horses in Europe are kept individually (in other studies it is up to 90%) and 16% of them are kept in groups. Almost all the activities of the horses depend on their movement and mobility. Analysis and observation done in the farms have shown that horses are motionless for a maximum of 23 hours a day and have activity for at most 4 hours a day. However, research shows that the horse health movement is particularly important for young horses (Petersen *etal*., 2006; Rose-Meierhofer *etal*., 2010). It is reported in the literature that the place of operation would help increase the activity (Rose-Meierhofer *etal*., 2010). In addition, it is found that feeding frequency in combination with the distance between functional elements has a significant effect on movement activity. The results of these studies show that there are various elements that can be implemented to increase activities such as automatic feeding. Shrubs and other elements should also be used to motivate animals to walk. Although big space increases activity, it does not have long-term effects as the nutritional system. Pedometer is a tool for measuring and monitoring livestock behavior. However, this tool is mainly used for the management of dairy cows to identify stress, which is the most important parameter for optimal fertility management. The pedometer records the activity and life of the animals as electrical waves (Brehme *etal*., 2008). Research on horse activity at various keeping places shows that the activity of the horse can be automatically measured using sensors. Figure 4 shows the data measured using this system.

[DOR: 20.1001.1.2717378.2020.3.6.3.7]

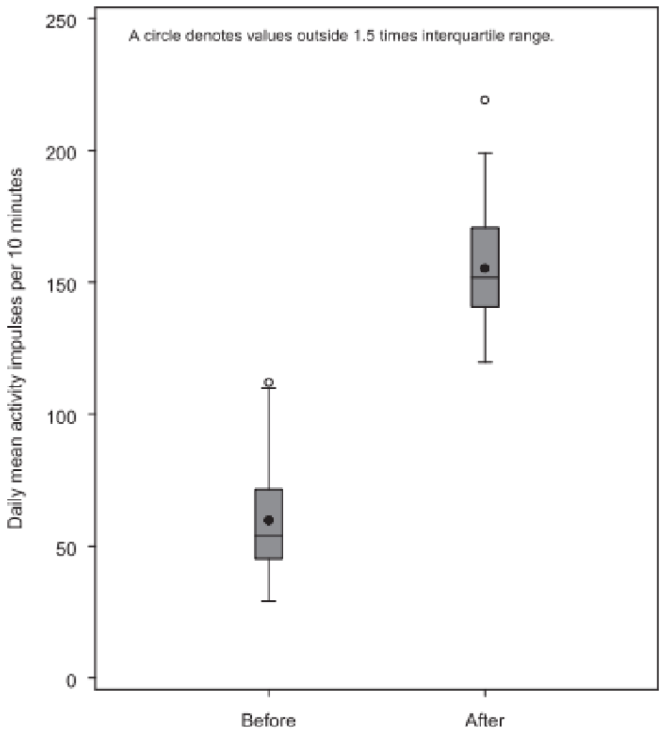

Figure4. Indicates horse activity within 10 minutes at various locations (Rose-Meierhofer *etal*., 2010).

Nutrition is a vital component of horse health. In horses a properly formulated diet can have a great impact on disease prevention. Among the diseases studied in these types of animals are diseases such as colic, orthopedic problems and obesity. It is more difficult to formulate a balanced diet for horses than other species because it has to be developed from several components (for example, forage and one or more concentrates) and the level of activity, life stage and individual changes of the animal must be taken into account (Hoffman *etal*., 2009). Since the horses have to live in areas with poor vegetation, they are accustomed to low energy and high fiber diet (McGreevy, 2004). In modern nutrition systems, horses are often fed a low calorie (twice a day) feed compared to living in the wild. Excess feeding on horses over a short period of time results in a high intake of starch and may not cause ulcers and gastrointestinal diseases (Hymøller *etal*, 2012). Horse chewing can be considered to evaluate horse feed intake. Horse feed behavior is defined as a prolonged interval of between 1 and 2 hours, which can be a tool for monitoring different diets. However, there are still many unanswered questions; for example, there is still no evidence of gastric ulcer disease in horses. Chewing is one of the important parameters having great impact on the evaluation of horse food consumption. Analysis of this parameter provides valuable information to reduce diseases such as gastric ulcer (Petersen *etal*., 2005; Bonin *etal*., 2007). In this regard, we

[DOR: 20.1001.1.2717378.2020.3.6.3.7]

can measure chewing activity and measure horse feed intake using the Rumi Watch System reported in the study (Werner *etal*., 2016).

Providing a model for developing a livestock farming system for keeping and breeding

Given the significant and measurable relationships between research parameters in this study, all parameters are analyzed and processed in a processor to provide a suitable and targeted program for breeding and sustaining of each animal.

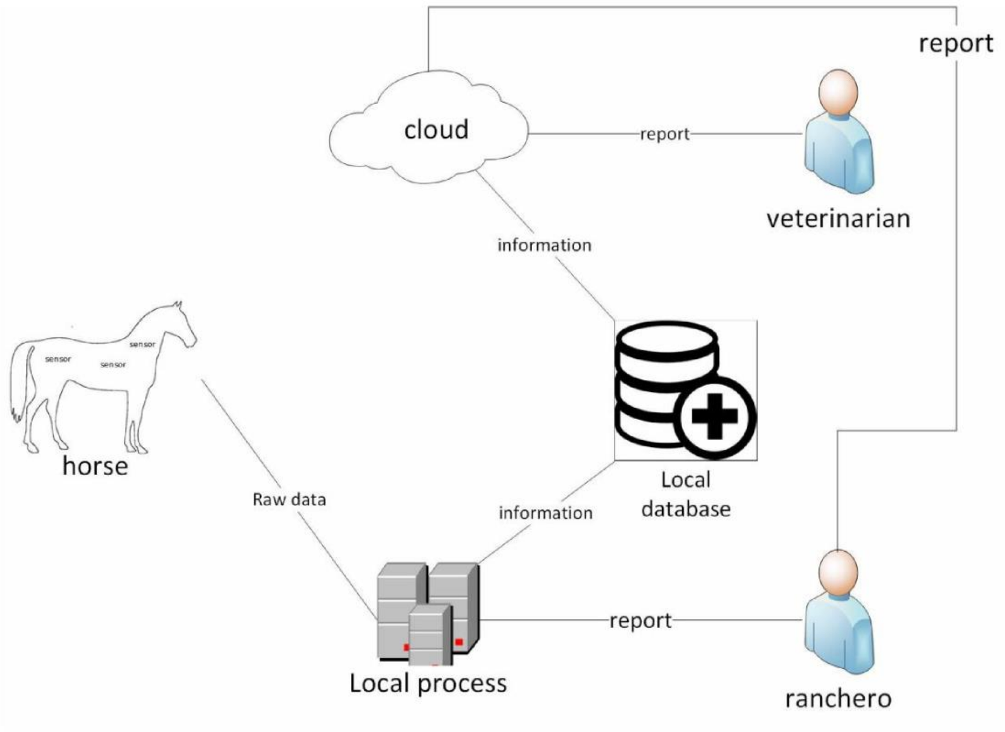

Figure5. A proposal for development of livestock farming system

According to recent research on horses, many parameters have been studied, each of which has had a significant impact on growth, keeping and breeding. Each of the research investigated and analyzed the parameters discussed in this article based on the need for research parameter or the needs of the farmer. These analyses and results have had significant contributions to horse keeping and breeding. Research parameters in addition to positive impacts on horses, have generated data for analysis in the future of the breeding process.

It also provides information on diagnosis and prescription of diseases about each one of the animals for veterinarian. Failure to transmit information on time and incomplete or incorrect information about livestock may result in losing each of them. Also, the lack of proper history about

[DOR: 20.1001.1.2717378.2020.3.6.3.7]

each animal may cause early diseases in them. Forgetting the duration of treatment, forgetting to use medications or veterinarian prescriptions are all essential elements for keeping livestock in their time of illness and may cause major problems for veterinarians. As mentioned above, all the parameters studied are effective on the growth, breeding and keeping of the horses. Based on the proposed model of this study, we examined all the parameters in a local processor for providing suitable and on time reports to the farmer and also for keeping good information in specific time periods as it is quite important in keeping and breeding as well as buying and selling livestock. Each of the parameters studied by the researchers proved to be high-value information and has had good results in horse breeding. In the proposed model we have considered all the parameters of core temperature, chewing, feed volume, activity and environmental information at one time in addition to keeping information at appropriate intervals as useful warning to the rancher in a local processor which can be managed by customizable software. Of course, there is the problem of lack of access to the public networks in this research project. When the rancher is in a public network, information is synchronized by software with the cloud servers provided by the plan. So, in addition to storing information in the local database, the information is exchanged at different times (in case of lack of access to public network in the livestock location) with the cloud server so that there would be a secure location for storing the livestock information. Also, it can receive the information from the cloud server using another customizable and manageable software and give it to the vet and the vet will provide the rancher with recommendations on each of the animals based on the information he received. This information is stored on the cloud server and transmitted to the rancher's software and, if public network is available, it is transferred to the local database to keep and analyze the livestock administration and records. In this model, an integrated relationship has been established between livestock, rancher, and veterinarian. In a local processor, all parameters are investigated by researchers for analysis of the growth, breeding and keeping the livestock. To the best of the researchers' knowledge in no similar project, all parameters have been investigated to increase the efficiency of horses. An illustration of the proposed model used in this study is shown in Figure 5.

Conclusion

The existence of livestock diversity and lack of proper history for livestock keeping causes many problems in animal husbandry. Using a livestock farming system and storing information about different parameters of the life of livestock will lead in an increase in the value of the animals and brings about positive impacts on keeping the animals as well as having positive effects on their health and proper appearance which are very important qualities. Through the livestock farming system, useful information about animal life can be attained. It could also increase the rancher's ability to breed and keep livestock's breeding data and use them for animal breeding, assisting the veterinarian to fight their diseases and maintain their good health which brings about success and wealth to the breeders.

References

Aerts JM, Wathes CM, Berckmans D. Applications of process control techniques in poultry production. BSAP Occasional Publication. 2001; 28:147-54.

Banhazi TM, Black JL. Precision livestock farming: a suite of electronic systems to ensure the application of best practice management on livestock farms. Australian Journal of Multi-disciplinary Engineering. 2009;7(1):1-4.

Banhazi T. Potential precision livestock farming technologies for the egg industry. Advances in agricultural technologies and their economic and ecological impacts. 2006; 1:45-7.

Black JL, Giles LR, Wynn PC, Knowles AG, Kerr CA, Jones MR, Strom AD, Gallagher NL, Eamens GJ. A review-Factors limiting the performance of growing pigs in commercial environments.

Bird N, Crabtree HG, Schofield CP. Engineering technologies enable real time information monitoring in pig production. BSAP Occasional Publication. 2001; 28:105-12.

Bonin SJ, Clayton HM, Lanovaz JL, Johnston T. Comparison of mandibular motion in horses chewing hay and pellets. Equine veterinary journal. 2007;39(3):258-62.

Brehme U, Stollberg U, Holz R, Schleusener T. ALT pedometer—New sensor-aided measurement system for improvement in oestrus detection. Computers and electronics in agriculture. 2008;62(1):73-80.

Brown–Brandl TM, Yanagi T, Xin H, Gates RS, Bucklin RA, Ross GS. A new telemetry system for measuring core body temperature in livestock and poultry. Applied engineering in agriculture. 2003;19(5):583.

Dijkhuizen AA, Huirne RB. CHESS-an integrated decision support and expert system to analyse individual sow-herd performance. InProceedings of the 3rd international congress for computer technology. Integrated decision support systems in agriculture-successful practical applications, Frankfurt aM-Bad Soden, May 27-30, 1990. 1990 (pp. 221-227). Deutsche Landwirtschafts-Gesellschaft (DLG).

Dunn M, Ludvigsen G, Banhazi T, Black J. Managing Growth Variability through Implementation of Precision Livestock Farming Systems. InSociety for Engineering in Agriculture 2007 National Conference: Agriculture and Engineering: Challenge Today, Technology Tomorrow 2007 (p. 23). Australian Society of Engineering in Agriculture.

Esslemont RJ, Wassell BR, Lamb J. DAISY-the dairy information system. InProceedings of the 3rd international congress for computer technology. Integrated decision support systems in agriculture-successful practical applications, Frankfurt aM-Bad Soden, May 27-30, 1990. 1990 (pp. 130-151). Deutsche Landwirtschafts-Gesellschaft (DLG).

Fox, DG., and Black, JR. A system for predicting body composition and performance of growing cattle. Journal of Animal Science, 1984; 58(3): 725-739.

Frost AR, Schofield CP, Beaulah SA, Mottram TT, Lines JA, Wathes CM. A review of livestock monitoring and the need for integrated systems. Computers and electronics in agriculture. 1997;17(2):139-59.

[DOR: 20.1001.1.2717378.2020.3.6.3.7]

Green AR, Gates RS, Lawrence LM, Wheeler EF. Continuous recording reliability analysis of three monitoring systems for horse core body temperature. computers and electronics in agriculture. 2008; 61(2):88-95.

Green AR, Gates RS, Lawrence LM. Measurement of horse core body temperature. Journal of Thermal Biology. 2005 Jul 1;30(5):370-7.

Hemsworth PH, Barnett JL, Beveridge L, Matthews LR. The welfare of extensively managed dairy cattle: A review. Applied Animal Behaviour Science. 1995;42(3):161-82.

Hoffman CJ, Costa LR, Freeman LM. Survey of feeding practices, supplement use, and knowledge of equine nutrition among a subpopulation of horse owners in New England. Journal of Equine Veterinary Science. 2009;29(10):719-26.

Hogewerf PH, Maatje K, Rossing W. Computer aided system for health and reproduction control in dairy cows. PUBLICATION-EUROPEAN ASSOCIATION FOR ANIMAL PRODUCTION. 1992; 65:483-483.

Hymøller L, Dickow MS, Brøkner C, Austbø D, Jensen SK. Cereal starch, protein, and fatty acid pre-caecal disappearance is affected by both feed technological treatment and efficiency of the chewing action in horses. Livestock science. 2012;150(1-3):159-69.

Janis C. The evolutionary strategy of the Equidae and the origins of rumen and cecal digestion. Evolution. 1976:757-74.

Jansen MB, Eradus W. Future developments on devices for animal radiofrequency identification. Computers and Electronics in Agriculture. 1999;24(1-2):109-17.

Kollis K, Phang CS, Banhazi TM, Searle SJ. Weight estimation using image analysis and statistical modelling: A preliminary study. Applied Engineering in Agriculture. 2007;23(1):91-6.

Korthals RL. Monitoring growth and statistical variation of grow-finish swine. InLivestock Environment VI, Proceedings of the 6th International Symposium 2001; (p. 64). American Society of Agricultural and Biological Engineers.

Landesberg P. In the beginning, there were Deming and Juran. The Journal for Quality and Participation. 1999;22(6):59.

Lokhorst C, Lamaker EJ. An expert system for monitoring the daily production process in aviary systems for laying hens. Computers and Electronics in Agriculture. 1996;15(3):215-31.

McGreevy P. Equine behavior: a guide for veterinarians and equine scientists. Saunders. An Imprint of Elsevier Limited. 2004.

Mitchell MA, Kettlewell PJ, Lowe JC, Hunter RR, King T, Ritchie M, Bracken J. Remote physiological monitoring of livestock–An implantable radio-telemetry system. InLivestock Environment VI, Proceedings of the 6th International Symposium 2001 2001 (p. 535). American Society of Agricultural and Biological Engineers.

Mottram T. Automatic monitoring of the health and metabolic status of dairy cows. Livestock Production Science. 1997;48(3):209-17.

Ordolff D. Investigations on the design of floats to control milk meters. Journal of Agricultural Engineering Research. 1989; 43:113-23.

[DOR: 20.1001.1.2717378.2020.3.6.3.7]

Pedersen BK, Madsen TN. Monitoring water intake in pigs: Prediction of disease and stressors. InLivestock Environment VI, Proceedings of the 6th International Symposium 2001 2001 (p. 173). American Society of Agricultural and Biological Engineers.

Petersen S, Tolle K, Blobel K, Grabner A, Krieter J. Evaluation of horse keeping in Schleswig-Holstein. ZUCHTUNGSKUNDE-GOTTINGEN-. 2006;78(3):207.

Petersen S, Tölle KH, Blobel K, Grabner A, Krieter J. Erhebungen zur Pferdehaltung in Pensionsbetrieben Schleswig-Holsteins. Mensch & Buch Verlag; 2005.

Rose-Meierhöfer S, Klaer S, Ammon C, Brunsch R, Hoffmann G. Activity behavior of horses housed in different open barn systems. Journal of equine veterinary science. 2010;30(11):624-34.

Schofield CP, Marchant JA, White RP, Brandl N, Wilson M. Monitoring pig growth using a prototype imaging system. Journal of Agricultural Engineering Research. 1999;72(3):205-10.

Schon H, Meiering AG. Computer-aided control improves livestock operations. Agricultural engineering (USA). 1987.

Shao B, Xin H. A real-time computer vision assessment and control of thermal comfort for group-housed pigs. Computers and electronics in agriculture. 2008;62(1):15-21.

Stafford JV. Implementing precision agriculture in the 21st century. Journal of Agricultural Engineering Research. 2000;76(3):267-75.

Street MJ. A pulse-code modulation system for automatic animal identification. Journal of Agricultural Engineering Research. 1979;24(3):249-58.

Werner J, Umstatter C, Zehner N, Niederhauser JJ, Schick M. Validation of a sensor-based automatic measurement system for monitoring chewing activity in horses. Livestock Science. 2016; 186:53-8.

Xin H, Shao B. Real-time assessment of swine thermal comfort by computer vision. InWorld Congress of Computers in Agriculture and Natural Resources, Proceedings of the 2002 Conference 2002 (p. 362). American Society of Agricultural and Biological Engineers.

[DOR: 20.1001.1.2717378.2020.3.6.3.7]