Digital Innovation on genetic improving livestock services

1. Abstract

In the world market, Brazil is the largest exporter of beef and it has the best genetic quality and the largest commercial herd of cattle in the world, with the predominance of the Nelore breed. In the PMGRN (Programa de Melhoramento Genético da Raça Nelore - Genetic Improvement Program for the Nelore Breed), the MGT (Mérito Genético Total - Total Genetic Merit) index gathers different predictions of genetic value, including the EPD (Expected Progeny Difference). The EPD is an index that results from the need for an increment tool to optimize the gains and efficiency of beef cattle, seeking the genetic improvement of the animal according to economically interesting characteristics, such as weight, length and musculature. Genetic improvement programs use objective growth characteristics, although there may be sources of error in measurements. There are important body dimensions that suggest the use of visual scores for a better description of morphological type, being considered a good way to identify animals with better productive conformation. Estimates of genetic parameters for visual scores show great variation and difficulty in comparisons. This variation results not only from the direct effect of real differences in genetic variances but also from the subjectivity of the methodologies used in data collection, which causes greater variations between evaluators. However, the different evaluation methods have in common the need for reliable collection of objective and morphological data from the animals to improve the quality and efficiency of the herd evaluation service. This project is multidisciplinary and aligns knowledge from Computer Science, Engineering and Veterinary. The objective is to identify the Critical Success Factors (CSF) in measuring herd characteristics. An initial literature review and interviews with veterinary professionals were carried out. The proposed model is expected to improve efficiency and to reduce the time for the herd evaluation.

Keywords: beef cattle, genetic improvement, herd evaluation, services innovation, computer vision.

2. Introduction

Since 2003, Brazil stands off on the global market, being the biggest exporter of bovine meat, the largest commercial herd of cattle and the best genetic quality (KOURY FILHO, 2005), with the predominance of the Nelore breed with 79% of the genealogical registers on the ABCZ (Associação Brasileira dos Criadores de Zebu - Brazilian Association of Zebu Breeders), situation that remains until 2020. However, the average indexes of productivity still show potential for improvement and one of the tools for improvement is the use of well-crafted genetic improvement programs, that allows the identification of the best individuals and using them as

breeders promoting cumulative genetic gain, enhancing favourably genes frequency and decreasing the frequency of unfavourable genes on the population.

About the existence of visual scores evaluation methods, according to Fries (1996), the use of visual scores in Brazil overlaps with the implantation of PROMEBO (Programa de Melhoramento de Bovinos - Cattle Improvement Program) in 1974, which recommended, in addition to weighing in strategic phases, the visual evaluation of animals based on two other methods (Conformation scores (BEEF, 1974) and Ankony evaluation system (LONG, 1973).

On the PMGRN (Programa de Melhoramento Genético da Raça Nelore - Genetic Improvement Program for the Nelore Breed), the MGT (Mérito Genético Total - Total Genetic Merit) gathers different predictions of genetic value for five characteristics, including the EPD.

What the evaluation methods have in common is the necessity of collecting, in the most reliable way, objective data and morphological data of the animal to improve the quality of the herd evaluation service. evaluators are trained, retrained and periodically undergo rhythm evaluation training, but the results obtained are always subject to bias due to the evaluator. In the case of the herd evaluation, this variability may also be caused by environmental difficulties such as heat or rain, in addition to the fatigue of the evaluator himself.

3. Problem to be solved

On one hand, the necessity of herd evaluation exists and the expression of Brazil on the meat market makes it urgent to seek actions to improve the evaluation. On the other hand, there are several opportunities for developing solutions and the advances in Information and Communication Technology (ICT), through technological platforms, provide new developments. Some of the questions that remain open about the direction of the research for solution in genetic improvement are: a) what technological resources to use and how to compose them to offer a solution to the market; b) what are the CSF, as defined by Rockart (1979) for a genetic improvement project using available technology; c) whether the development of new technological solutions favor the emergence of new business models for professionals and companies working in the livestock sector, in the herd evaluation.

in short, the problem to be solved and defined in this project are:

1. lack of reliability and precision in collecting data on morphological and functional characteristics such as "Conformation", "Precocity" and "Musculature", which directly affect the calculation of EPD. There is a strong influence of human subjectivity on the calculation of EPD for these characteristics of interest for selection, generating great uncertainties and decreasing accuracy of the evaluation, according to the current methods of collecting data about these characteristics in herds.
2. The time taken to evaluate the herd is long, depending heavily on the professionals who carry out the evaluations.

3. The influence of the human factor on the calculation of the EPD, determination of the morphological characteristics, which generates great uncertainties and decreases the accuracy of the evaluation.

4. Research goals

This research project, in its first phase and subject of this article, has the specific goal of identifying the CSF for the service of acquirement and evaluation of phenotypic characteristics of beef cattle, consistent with the following purposes:

1. Enhance the precision in the evaluation process;
2. Accelerate the phenotypic evaluation process;
3. Development of devices and sensors for image acquirement and data acquirement relevant to the statistical analysis and the health of the animal;
4. Development of a systematic approach to image acquirement of the cattle and measurement of the phenotypic characteristics of the cattle;
5. Development of a business model for the service of cattle genetic improvement.

5. Justification (importance for companies and organizations)

Brazil uses EPD in order to improve the genetic quality of herds. The interest characteristics determination in the calculation of the EPD, to guarantee a better accuracy in the index, makes it possible to generate a higher quality final product, increasing the producer's gains, decreasing the "waste" in livestock production and bringing benefits for society, given that the world population has been growing and, consequently, the protein consumption has been growing as well. In addition, the possible trade-in sperm from cattle with the desired characteristics can be a source of income for the producer.

In the United States, since the late 1960s, all cattle from Angus breed (the first to use EPDs) that participates in exhibitions must have this data and the judges select the champions based on the sum of the phenotype plus the EPDs, due to the fact that only this way results in truly genetic improvement. Currently, the American Angus Association does not register any Angus product without EPDs. Whereas in Brazil and other Latin American countries, EPDs are not mandatory to register animals or to participate in exhibitions.

6. Research differentials

The academic environment is trying to align multidisciplinary approaches to the development of technological solutions with the participation of professionals with different levels of experience. In this context, the research project has as differentials, the multidisciplinary work with researchers in different disciplines, such as Industrial Engineering, Computer Engineering, Mechatronic Engineering, Computer Sciences and Veterinary Medicine; contact with different experts from multiple organizations. Furthermore, the research proposes an innovative solution to

a real problem using technology in a sector that could benefit highly of such an approach, impacting many people, directly and indirectly.

7. Client companies and activity sector

The most recent approaches to project development have emphasized the involvement of clients from the project beginning, among which stand out Design Thinking (BROWN, 2010; KNAPP et. al., 2017) and Agile Methods (AMARAL, 2011; RUBIN, 2017). In this project, the customers identified are:

a) Genetic improvement service organizations applied in large Veterinary;
b) Beef cattle breeding and breeding farms;
c) Associations of ranchers;
d) Genetic breeding programs that seek herds genetic improvement by acting in accordance with the requirements from the Brazilian Ministry of Agriculture, Livestock and Supply (Ministério da Agricultura, Pecuária e Abastecimento).

8. Research Method:

This genetic improvement project has two methodological characteristics relevant to its nature: 1) the final results are not known at first and depend on the participation of specialists (veterinarians) and ranchers during the project, which refers to the research-action method (COUGHLAN and COGHLAN, 2002); 2) co-design with suppliers involvement (stakeholders and specialists) in developing the solution "concept", sharing communication in the seek for the solution (SPINA et. Al 2002) to decrease the total project time.

The first phase of the project, for the identification of CSF, includes the following aspects:

a) Initial review of the literature on genetic improvement and evaluation of EPD;
b) Identification of cases in the literature on the application of EPD with results, benefits and limitations;
c) Identification of image processing application cases already conceived on the market and understanding of technological and organizational limitations;
d) Field interview with a veterinarian professional with experience in Computer Science;
e) Field interview with a veterinarian professional with experience in activities of herd evaluation, animal breeding of beef cattle and annual recycling training in cattle evaluation.

9. Literature Review

a. Overview of the bovine herd evaluation

Different approaches have been applied to breeding cattle. The application of genomics in animal reproduction and the ability of manipulating it in a way that benefits people is a theme that dates back to the beginning of genetics studies (CALUS, 2009; BLASCO; TORO, 2014, apud KOURY FILHO, 2005). Research on genomics for the improvement of herds has also attracted the attention of researchers since the early 1990s (ROTHSCHILD; PLASTOW, 2014 apud KOURY FILHO, 2005).

Genetic improvement programs use growth characteristics, such as: standardized weights at different ages, weight gains and days to reach certain weights, these are called objective characteristics, although, according to Carvalheiro et al (1988) apud KOURY FILHO (2005), there may be sources of errors in weighing. Measures such as body dimensions (e.g. height) are also important Teixeira et al. (2002) and the use of visual scores (FARIA, 2007) for a better description of the morphological type. The evaluation by visual scores is considered a good way to identify animals with better productive conformation. The visual scores of Conformation (C), Precocity (P) and Musculature (M) are characteristics that can be directly selected (PONS et al., 1989; LIMA et al., 1989; PONS et al., 1990; ROBINSON et al. , 1993; ROSO & FRIES, 1995; ELER et al., 1996; CARDOSO et al., 2001; KOURY FILHO, 2001; JORGE JÚNIOR, 2002; VAN MELIS et al., 2003; CARDOSO et al., 2004, apud KOURY FILHO, 2005).

According to Cardoso et al., (2004), apud KOURY FILHO (2005), the characteristics of genetic parameters found in the literature for visual scores show great variation and difficulty in comparisons. This variation results not only from the direct effect of real differences in genetic variances but also due to the subjectivity of the methodologies used in data collection. Environmental factors also make this assessment difficult. It is worth stating that different models can also affect the result of the genetic parameters characteristics.

Another evaluation method, which will be further explored in the this literature review, is the EPMU - Estrutura Corporal, Precocidade, Musculatura e Umbigo (Body Structure, Precocity, Muscularity and Umbilicus), created with the objective of testing and incorporating this method by the PMGRN (Programa de Avaliação Genética da Raça Nelore - PMGRN/USP - Nelore Breed Genetic Evaluation Program), supported by the ANCP (Associação Nacional de Criadores e Pesquisadores - National Association of Creators and Researchers) (ANCP, 2004).

Despite its evaluation inaccuracies, the human eye is the oldest bovine selection tool that meets the characteristics desired by man and an empirical visual evaluation continues to be used in certain situations, such as: a) criteria for purchase and disposal of animals ; b) granting of genealogical records by technicians from associations of the most diverse bovine breeds; c) in comparative judgment in agricultural research tracks and in targeted mating,

in which many professionals analyze the animals' exterior in addition to genealogy data, phenotypic performance and performance in genetic evaluations, when existing.

b. Beef cattle methods of evaluation

The knowledge related to visual assessments dates back to the beginnings of Industrial Engineering, with the Studies of Times and Movements and the Engineering of Methods (BARNES, 1977). The examples cited illustrate situations in which man uses visual appreciation in an empirical way - although there are archetypes advocated by race associations and personal experiences - there is room for particular preferences and interpretations. The methods seek to minimize the personal influence of the evaluator and, thus, generate appropriate data to compose the characteristics analyzed by genetic evaluations. According to Fries (1996), absolute scoring systems tend to constrain the evaluators, and result in an extremely concentrated set of data around a value considered as good. This author suggested systems of conceptual notes and related to the group of contemporaries, seeking to achieve better distribution of scores. It is worth mentioning that IoT (Internet of Things) is the original technological platform for the digital transformation that is radically changing the economy and society (KRANZ, 2018). This technology triggers the automation of processes in which labor represents a significant component, providing revolutionary applications, new business models (PIGNEUR; OSTERWALDER, 2011) and new service activity flows. This is the appropriate technological scenario for improving data collection for the calculation of EPD.

c. Technological availability for capturing herd data

There are new factors in livestock operating environment, such as: a) availability of technological resources for the development of devices to capture the dimensions of animals, such as their weight, physical dimensions, vital signs such as pulsation, blood pressure, among others; b) software resources to capture information about positioning, distance covered, number of steps per day, or animal unrest; c) devices for capturing images of animals at varying distances in relation to the reference equipment or environment, animals in motion and in large quantities, equipment and programs for image treatment allowing estimation of parameters so far observable with the naked eye (such as musculature, size or appearance of the animal), d) equipment for image treatment, possibly allowing a more accurate assessment of animal dimensions, which was necessarily done in the field, and now it can be done in a more controlled environment of temperature, humidity and lighting conditions.

d. EPD - Expected Difference in Progeny

Since the early 2000s, there has been a great need for the Brazilian agricultural sector to increase gains based on productivity, since the high costs involved in raising beef cattle and in slaughter, in addition to the logistical costs involved in distribution, mainly in exports, make the product more expensive, making it less inviting to large markets such as the European and the Chinese. As pointed out by KOURY (2005), the greater opening in the world meat market brings comparisons in relation to quality, production systems and costs. As highlighted by Luciari Filho (1999 apud KOURY, 2005), beef is considered a food of high biological value. Brazilian beef cattle has been undergoing a dynamic process of changes, constantly emerging new challenges, related to new opportunities, with an estimated growth of 200% in world meat demand by 2025. It is also relevant to increase the quality of Brazilian Nelore cattle, which can be better quantified with a good evaluation of the herd.

EPD is an index that comes from the need for an increment tool to optimize the gains and efficiency of beef cattle, thus seeking the genetic improvement of the animal according to economically interesting characteristics. EPD is the expected difference in the average of the progenies of a certain animal in relation to the average of the progenies of a group of reference animals that participated in the same evaluation, when mated with individuals that have, on average, the same genetic potential. EPD is expressed in the original unit of measurement for the characteristic in question: kg, days, g/day, cm, cm2, mm, etc., for example, body weight, age at first delivery, average daily gain weight, scrotal perimeter, loin eye area and subcutaneous fat thickness, respectively, allowing a direct interpretation of the differences between animals. In the genetic evaluation programs developed by Embrapa Gado de Corte, the benchmark for calculating EPDs is the population average. Thus, for each characteristic, in the same evaluation, a similar proportion of positive and negative individuals is expected.

EPD is an estimate of half of an individual's additive genetic value and it is a fundamental tool for comparison between individuals in the most varied environments, enabling users of this information to make a more correct choice of animals that should be reproduced or discarded from cattle herds, aiming greater beef cattle gains and efficiency and focusing on the genetic improvement of animals according to economically interesting characteristics.

EPD is considered one of the most modern tools and it is possible to estimate how the future descendants of a given breeder will express its characteristics. Therefore, it predicts the performance of the offspring of a given breeder compared to the performance of the offspring of all breeders included in the genetic evaluation program and mated with similar cows, in

other words, within the same management group (animals born at the same time and exposed to the same environmental conditions). The EPD index is calculated by analyzing several factors of interest, which includes characteristics that are more easily measurable, such as the weight of the animal in some stages of life, such as birth and weaning, which can be obtained with appropriate equipment, like a scale. Other characteristics evaluated are of genetic aspect, thus, they are analyzed in the laboratory and are related morphological characteristics, which are determined by the evaluation made by a specialist who assigned scores within a scale for the given management group. It is clear, therefore, that despite the credibility and expertise of the specialist in question, within the assessment of such morphological characteristics, there is a human error factor, which decreases the accuracy of the EPD. Moreover, the time taken by the specialist to make the evaluations can be significant, which can represent an increase in producer costs and time to calculate EPD and also a decrease in accuracy.

In large populations, the calculation of accuracy demands more computationally. For this reason, it is important to determine the degree of reliability in the genetic value, according to (GARNERO et al., 2002, apud KOURY, 2005).

According to KOURY (2005), what is evaluated in each characteristic is:

1) Body Structure (E): visually predicts the area that the animal covers seen from the side, basically evaluating body length and rib depth. Larger areas correspond to higher scores;

2) Precocity (P): in this evaluation, the highest scores is given to animals of greater proportion between the depth of ribs and the height of their limbs. In practice, especially at younger ages, animals often do not yet have cover fat. The objective is to identify the “design”, based on proportions, that corresponds to individuals who will deposit finishing fat earlier, with the expectation that they will be those with more ribs in relation to the height of their limbs;

3) Muscularity (M): muscularity is assessed by evidence of muscle mass, with individuals who are “thicker” and with more convex musculature, in relation to the average of the lot, receive the highest grades and the “thinner” and with less convex musculature, rectilinear and even with hollows through the body, receive lower grades.

The scores attributed to the characteristics E, P and M allow to have a spatial conception of the animal, since E estimates the area that it covers laterally and that, in a very rudimentary way, will form a rectangle. The E characteristic, analyzed together with the P characteristic, will indicate the proportions of the sides of this rectangle. When the score for M is included, the third dimension will be given. The parallelepiped formed reflects the

estimate of the individual's relative volume and proportions, as can be seen in Figure 01. This conception becomes more precise when adding the rear weight and height data;

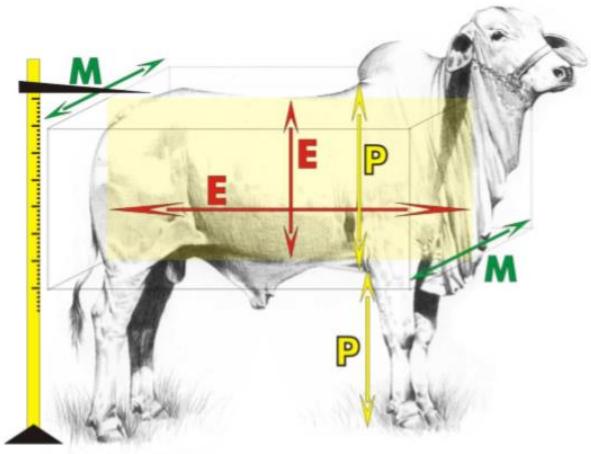

Figure 01 - Adapted from KOURY FILHO, 2005

According to veterinary professionals, EPM continues to be the most well-known and used method of visual assessment by scores in Brazil, consisting of assigning scores individually to each animal following procedures widely used in the field.

In addition to the challenge of obtaining reliable and accurate data for the calculation of the EPD of a given herd, the service for obtaining these data becomes a service that in itself adds value to the herd estimate. In order to make this service feasible, it is necessary to develop and test a business model that enables the service to obtain and commercialize this data for the EPD calculations. In this way, the data has, at least, two different customers: the companies that do the calculation of the EPD, some of them accredited in programs of the Ministry of Agriculture, and the farms that seek to make business decisions based on elements obtained with scientific basis.

10. Product

The product aims the use of 3D scan cameras, such as the Microsoft Xbox Kinect, as we can see by the Figure 02, the camera has an IR sensor with which 3D measurements can be made with respect to distance from the camera. By taking pictures from different sides, it is possible to create a cloud of points, resulting in a 3D virtual model of the image with a relative real scale.

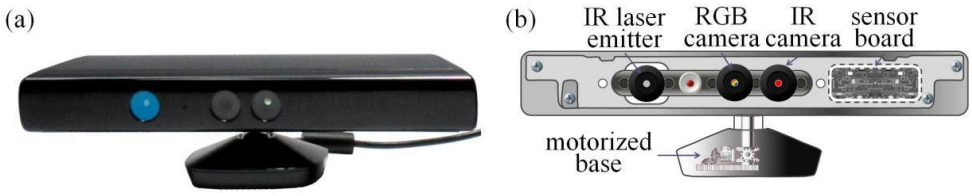

Figure 02 - Adapted from MARINELLO et al., 2015

The Figure 03 shows an example of a possible setup to make the measurements. To avoid the interference of the different IR cameras with each other, the pictures cannot be taken simultaneously, due to the fact that the projected IR pattern from one camera can be mistakenly read from the detector of the other camera. But as (MARINELLO et al., 2015) stated, it is not a problem, since the Kinect, for example, can work on a frame rate of about 30 Hz, consequently, a whole set of measurements can be done in less than 0.2 seconds.

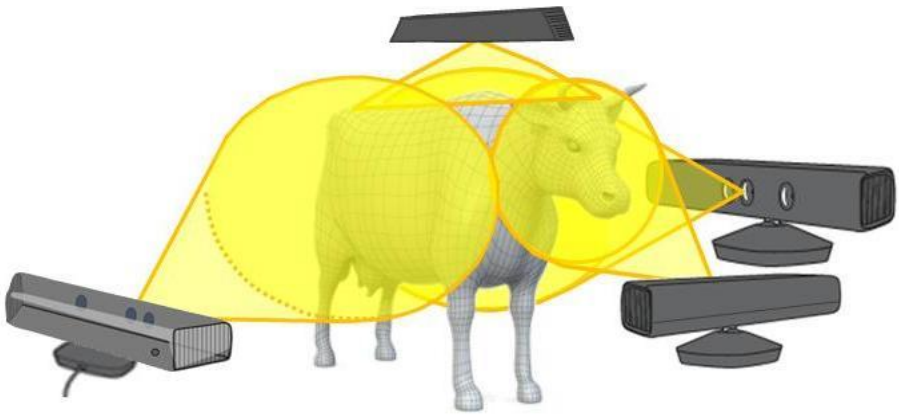

Figure 03 - Adapted from PEZZUOLO et al., 2018

It is significant to say that the sensors must be calibrated in respect to the distances they are from where the individual will be standing when the measurements are taken. Further information regarding calibration methods can be found at (PEZZUOLO et al. 2018).

The point cloud will be made by taking the output from the cameras, that are in spherical coordinates with origin on the camera itself, applying transformation matrices to take them to a shared cartesian coordinate system so that we can merge them in one final point cloud, an example can be seen on Figure 04.

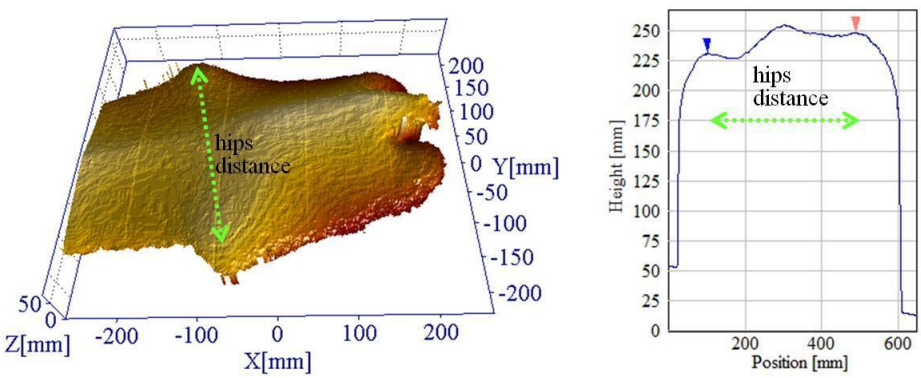

Figure 04 - Adapted from MARINELLO et al., 2015

With the 3D model from the point cloud, it is possible to measure body characteristics of interest and, with a further analysis of the whole management group, the EPDs of the individuals can be calculated, thus, the genetic evaluation.

11. Results and Conclusions

Open interviews were conducted with veterinary professionals, the first results of the project were obtained. In an interview with two veterinary professionals, from FMVZ (USP-Pirassununga), Department of Animal Nutrition and Production, and from UNESP Araçatuba, they were identified as CSF, translated as paths for the development of the project:

1) Development of devices to obtain objective measurements of cattle;

2) Development of evaluation programs (software) for handling information related to the cattle under study. As some characteristics to be measured may not be relevant for different herds, the programs must be modular, including multiple applications, for the same devices installed on the animals;

3) Capture of images of the herd and each individual to assess morphological characteristics; and

4) Elaboration of existing business models to provide EPD calculation service in cattle herds.

A new business model was also identified, which consists of providing resources for herd evaluation, supplying an external customer to calculate the EPD and having the herd owner as the second level customer.

In addition, it is intended to use the product model shown in a similar setup to actually go into a livestock ranch and make measurements and further analysis to determine the EPD for the herd in study and compare it to the results made by an specialist to compare accuracy.

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