Mobile Device and Software for Automating Body Measurements in Sheep

Abstract

In sheep farming, the process of body measurement of animals is of fundamental importance, as they are hereditary characteristics, which reflect on meat production and body development. However, breeders still perform body measurements on animals, mostly by manual methods. The objective of this article is to present a computational solution, composed of a mobile device for automating data collection in sheep, through sensors, in addition to a software to process and find body measurements. For the proposed solution, the mobile device was built using Arduino technology with sensors, and the software was developed in RubyOnRails framework. To validate the computational solution, measurements were made with manual equipment (current solution employed by the producers) and compared using the error to identify the noise caused. Thus, the average relative errors of 7.44 % for withers height, 7.61 % for rump height, 7.19 % for chest girth, 6.45 % for body length, 13.48 % for Weight and 10.76 % for Depth, presenting the mean and standard deviation of automatic measurements close to manual measurements. It is concluded that the body measurements performed in an automated way, allow greater agility in the measurements, in relation to the traditional (manual) measurements, which require a lot of work with the animal in the correct measurement posture and demands time.

Keywords: Sheep, Automation, Software, Embedded System

1. Introduction

Sheep farming is an activity that have proven to be a source of income and food security for the population in arid and semi-arid regions, due to the adaptation of these animals to hostile conditions. Thus, these activities are of great cultural and social importance in these regions.

It is important to consider that body measurements influence the standardization of the animal. These quantitative measures, such as withers *Withers Height* (WH), *Rump Height* (RH), *Body Length* (BL), *Chest Girth* (CG) and *Weight* are important in assessing the growth of the animal ([13]).

Currently, body measurements in animals are performed by manual methods, using the hypometer and tape measure. This method requires a lot of work with the animal in the correct measurement posture and still takes time. With the use of a computer system, it is possible to have access to a device that allows a quick collection of data and access to information that is stored in a database safely.

For the success of sheep farming, it is imperative to improve the production rates of the herd, in addition to the need to reduce the cost of animal production. Currently, producers have critical demands for technological innovations that allow them to obtain quality and standardization requirements for the herd. Thus, with the need for constant innovations that allow the improvement in the quality of animal production, challenges and opportunities are provided in the area of research and technological development. In this way, an unprecedented development in society is promoted.

The purpose of this article is to present a computational solution, composed of a device for automation of data collection by sensors and software capable of processing body measurements in sheep. As a result, the measurements are calculated using a mathematical model, being possible to store them in a database, allowing the monitoring the animal's measurement history.

2. Body Measurements

Measurements are used in animals to evaluate performance, characterize genetic groups and estimate live weight ([11]). Body weight varies according to genotype, sex, age and food system, among others, being of great importance to determine homogeneity of the products to be sold ([8]). According to [2], knowledge of body measurements and their correlations with the animal's live weight are strategies commonly used in sheep selection and production programs. Weight and measurements generally correlate positively, and it is acceptable to use them to predict the development of lambs from birth to weaning ([4]).

Comparative studies of morphological aspects in vivo are important, as they allow comparisons between racial types, weights and feeding systems, being a practical and low-cost method, requiring only good evaluation by a trained professional. The growth curves can assist in the establishment of specific feeding programs and in the definition of the optimal slaughter age ([1]).

According to [7], body measurements are grouped according to the regions of the animals body, in cephalic, trunk and limb measurements. The trunk measurements correspond to the *Chest Girth* (CG), which comprises the measurement of the chest girth, passing the measuring tape just after the withers and behind the scapula; *Body Length* (BL) is the measured distance from the scapular-humeral joint to the extremity of the *ischium*; limb measurements are *Withers Height* (WH), vertical distance from the highest point and the ground; *Rump Height* (RH), vertical distance from the highest point of the rump, in the space defined by the spinous process of T5 - T6 over the *sacral tuberosity* of the *ileum*, to the ground. The Fig.1 illustrates the measurements of the region of the trunk and limbs in sheep. The number 8 comprises the BL, 11 identifies CG, 16 WH and 18 RH.

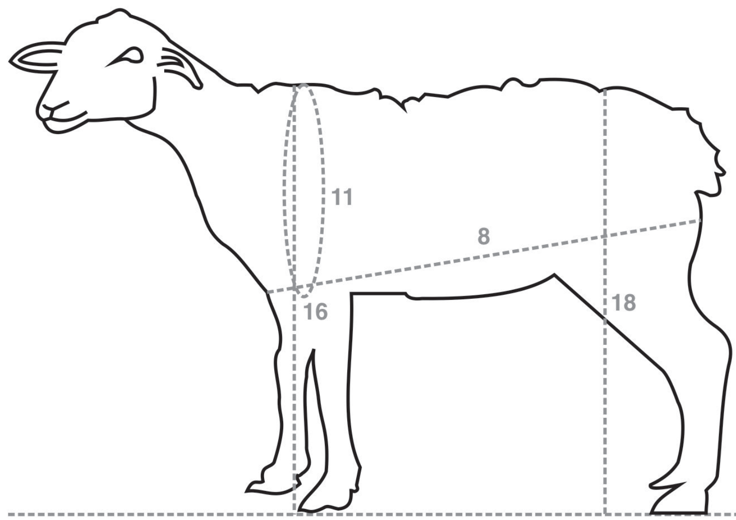

Figure 1: **Body measurements in the trunk and limbs in sheep**

8- Body Length, 11-Chest Girth, 16-Withers Height, 18-Rump Height Source: Oliveira et al. (2014)

Measurements are important in sheep production, as they can be used to predict the characteristics of commercial sheep carcasses, are performed on animals in vivo, with the purpose of acting on the standardization of the product ([9]). In [13], the sheep body length was used to predict weight, so it is of great importance, as it can reflect production performance.

3. Materials and Methods

3.1. Computational System - Overview

For the development of the computer system, hardware and software were used in order to automate data collection and obtain body measurements, as well as the weight of sheep, through the capture, processing and storage of information.

As for the software with mobile telemetry (*TMovCapri*) for body measurements, it consists of the following program modules:

- **Serial/USB port reading module** - allows the computer to communicate with the computing device, in which the captured information is stored in a file called *"serial_read.txt"*;

- **Valid reading module** - responsible for reading the file *"serial_read.txt"*. It analyzes each line, generating the file *"valid_readings.txt"* for each animal that exceeds the computational device. This is necessary for removing inconsistent reading in the data collection process;

- **Measurement calculation module** - from the reading of the file *"valid_readings.txt"*, the height of the rump is calculated, and by means of this, the height of the withers, chest girth are calculated (predicted), depth, animal length and weight.

Other modules correspond to the configuration of the device for communication with the computer, as well as the research module that makes it possible to consult the body measurements saved in the database in a given period, and a module to generate a graph and monitor the evolution of these measurements. The Fig.2 illustrates the proposed computational system for body measurements.

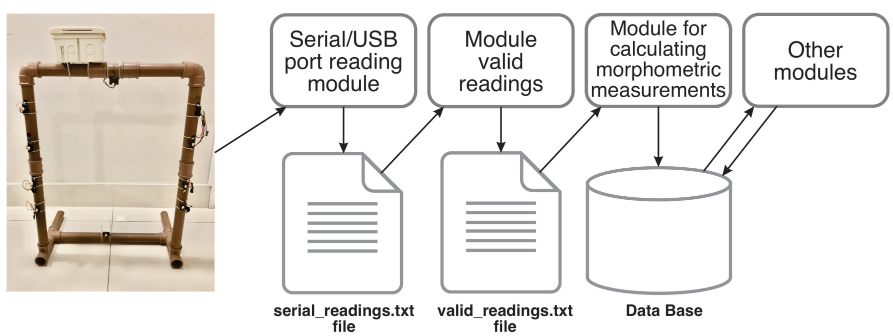

Figure 2: **System proposed and developed**

The mobile device for automation of body measurements was built from the *Arduino Mega 2560 board*, from the Sharp model GP2Y0A02YK0F infrared sensor and capacitors to filter out noise from the reading of the sensors.

3.2. Software for body measurement in sheep with mobile telemetry (TMovCapri)

For coding TMovCapri, *Ruby on Rails* was used, which is based on the Ruby object-oriented language. The information was stored in the *SQLite* database, written in C language.

The program module for reading the USB port was created to capture the distances read by the sensors. The *Ruby-Serial-Port* library was used, which provided facilities for communication between the device and the computer. To store the data in the file *"reading.txt"* on the computer, captured by the device, the following steps were performed:

- The configuration of the device was searched in the TMovCapri database. - A communication process was created with the computer's USB port in which the parameters are configured (port path, send rate, start bits, stop bits). - The file *"reading.txt"* is opened for writing, in which the data read by the sensors are stored. - When the data capture of each animal is finished, communication with the USB port is terminated and there is no more writing in the file *"reading.txt"*.

In the automatic measurement, each animal overtaking the device, has the information on the start and end time of this act stored in the *"reading.txt"* file, an identification tag is generated that allows identifying the animal that has passed the device at the time of measurement where they are recorded in the readings table of the TMovCapri database.

During the measurement process there is no physical contact with the animal. The Fig.3 illustrates the animal as it passes through the device placed at the exit of the brete, where the data is captured using the mobile device.

3.2.1. Definition of the regression model for the calculation of body measurements

Data collection is important in the measurement automation process, as it allows defining the regression model to represent the measurements: *Withers Height* (WH), *Body Length* (BL), *Chest Girth* (CG) and *weight*.

Figure 3: **Capture of data using mobile device**

For validation purposes, measurements were made on 40 fasting female Dorper ewes, aged between 12 and 48 months, at the *Technical College of Teresina/UFPI*. With the aid of the hypometer, a tape measure, both marking the measurements in centimeters, WH, RH, BL, CG, depth, weight were obtained by means of a scale. These measurements were used to define the regression model, before we started collecting data with the mobile device.

To assess the relationship between RH (obtained by the sensor) and other quantitative measures, *Pearson's correlation* is used, calculating the value of *Pearson's correlation coefficient*(r). Table 1 shows the correlated data of quantitative measurements between RH and other dependent variables WH, BL, CG and Weight. The correlation between WH and RH is very strong, whereas with BL, CG and Weight are moderate.

The collected data are stored in electronic spreadsheets and using the *R soft-*

Table 1: Correlation of GA with BL, CG and Weight

Body Measure	**Correlation of Pearson(r)**
WH-RH	0,99
BL-RH	0,62
CG-RH	0,60
Weight-RH	0,65

WH = Withers Height, RH = Rump Height, CG= Chest Girth, BL = Body Length

ware, the simple linear regression model and second degree polynomial regression model are defined, to obtain the WH, BL, CG measurements, and finally, the weight from of RH. Table 2, shows the linear and polynomial regression models.

Table 2: Linear and polynomial regression models

Linear Regression	**Polynomial Regression**
WH = 2,862 + (0,921 * RH)	WH = -56,234 + (2,943*RH) - (0,017* RH^2)
BL = 7,049 + (0,951 * RH)	BL = 45,935 - (0,379 *RH) + (0,011* RH^2)
CG = 14,733 + (1,121 * RH)	CG = -29,488 + (2,633 * RH) - (0,012 * RH^2)
Weight = -58,526 + (1,711*RH)	Weight = 51,138 - (2,015 * RH) - (0,031 * RH^2)

WH = Withers Height, RH = Rump Height, CG= Chest Girth, BL = Body Length

To define the adopted regression model, calibration (a set of data are observed) and validation (performance evaluation of the model) are required. In the calibration, the model parameters are selected to adjust them based on the comparison between the values measured manually and those predicted by the models. The values of these parameters are adjusted by a statistical process, to obtain and optimize an indicator. Thus, the accuracy of the linear and polynomial regression model is verified, calculating the *Root Mean Square Error* or RMSE, according to (Equation 1), where Ei = *estimated value*, Oi = *measured value* and n = *number of observations* ([10]).

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(E_1 - O_i)} \qquad (1)$$

To validate the model, analysis of variance (ANOVA - dealing with tests of population means) was used. From this, the p-value Pr(>F) was obtained, which represents the probability of the difference observed between treatments being due to chance and not to the factors studied. Table 3 represents the ANOVA statistical calculation, the variable y is predicted, and ŷ = residual (error) ([12]).

Table 3: Analysis of Variance (ANOVA)

Variation source	**GL**	**SQ**	**QM**	**F Calculated**
Regression	1	SQR = SQT − SQE	SQR/gl	QMReg/QMErro
Error (residue)	n - 2	SQE = $\sum(y - \hat{y})^2$	SQE/n - 2	—–
Total	n - 1	SQT = $\sum(y - y)^2$	—–	—–

n = total amount of data, y = predicted, ŷ = residual ,GL = Degree of freedom, SQ = Sum of squares, SQT = Sum of total squares, SQE = Sum of squares of error, QM = Medium squares, QMReg = Mean regression square, QMErro = Mean error square. Fonte Walpole, 2009

In the response of the hypothesis tests, a value is compared with the value of the test power, called p-value (level of significance observed), which represents a lower level of significance where H0 would be rejected. The p-value is obtained from the sample and the significance level of 5% (denoted as) was fixed before data collection. Table 4 shows the Pr (> F) obtained from the analysis of variance and RMSE for the linear and polynomial regression model.

The p-value calculated above was greater than , implying the non-rejection of H0 (equality of variances). Thus, the regression and polynomial models are significant at the level of 5%. Checking the RMSE values of WH, BL, CG and weight, we see that in linear regression the values are approximately 17.0 % for WH, 5.6 % for BL, 12.5 % for CG and 3.5 % for weight, smaller than in

Table 4: Pr (>F) e Root Mean Square Error

	Linear Regression		Polynomial Regression	
	Pr(>F)	RMSE	Pr(>F)	RMSE
WH	2,2e-16	1,2 cm	<2e-16	1,4 cm
BL	2,587e-06	3,6 cm	3.445e-06	3,8 cm
CG	4,728-06	4,8 cm	6.222e-06	5,4 cm
Weight	7,847e-07	5,9 kg	1,181e-06	6,1 kg

RMSE = Root Mean Square Error, Pr(>F) = p-valor

polynomial regression.

Based on the described regression models, the simple linear regression model was used, due to the efficiency in the prediction of WH, CG, BL and weight, from the height of the animal's rump. This model was used to code the program module that predicts body measurements (WH, BL, CG and weight), which are calculated from RH. The rump height (RH) is calculated by reading the sensor (A8) installed at the top of the device, as there is the height of the device and the distance that was read by the sensor, in the "reading.txt" file. For the RH calculation, the content of the final part of the file (25 %) is considered, as this measure is located on the animal's posterior part. The depth of the animal is obtained from the difference of withers height (WH) and the value read from the sensor at the bottom of the device (A7).

3.3. Mobile device

For the development of the mobile device, sensors from various manufacturers were tested, such as the *ultrasonic HC-SR04* and Sharp's infrared sensor. When calibrating the sensor, the reading never reached the operating distance mentioned by the manufacturer.

The mobile device for automating body measurements in communication with the WEB software is represented in Fig.4. This device was developed according to the following components: PVC pipes 40 mm (mm), plastic box, PVC 90 ° knees of 40 mm, PVC 90 ° 40 mm, Sharp infrared sensor, *Arduino Mega board 2560*, 10 uF capacitor and 0.50 wires.

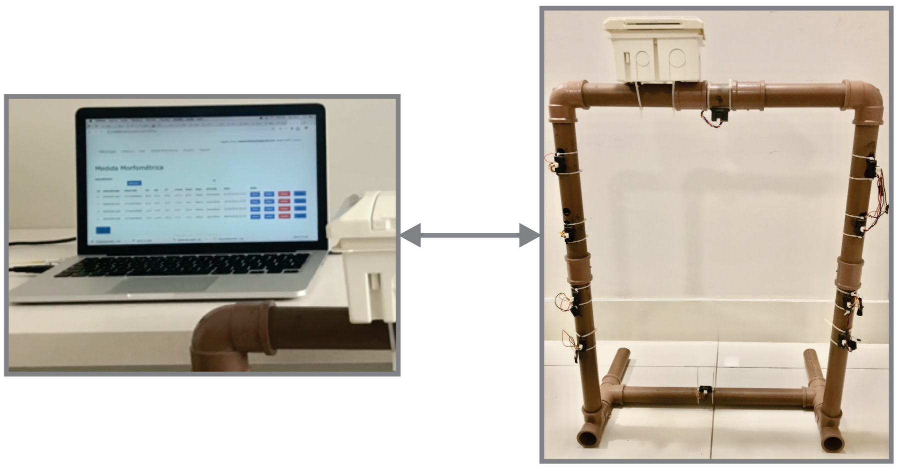

Figure 4: **Computing device in communication with the Web software**

The *Arduino Mega 2560* board is located inside a plastic box attached to the device. To reduce noise, it is necessary to install a 10 uF capacitor between the ground pin and the voltage input of the sensor, which collects the readings in voltage format, when finding the animal in its range. The software built into the *Arduino Mega 2560* converts voltages to distances in centimeters.

4. Results and discussions

4.1. TMovCapri

The developed TMovCapri is a specific software for body measurements, which works using a web browser, allowing access to the information stored in the database. To demonstrate the results obtained with the software development, some interfaces are illustrated, each one with its function.

To access the TMovCapri the web server needs to be running and the application can run on the computer itself, being accessible through the following URL http://localhost:3000. In Fig.5 the body measurements of the animals are presented, by pressing the menu *Body Measurements*.

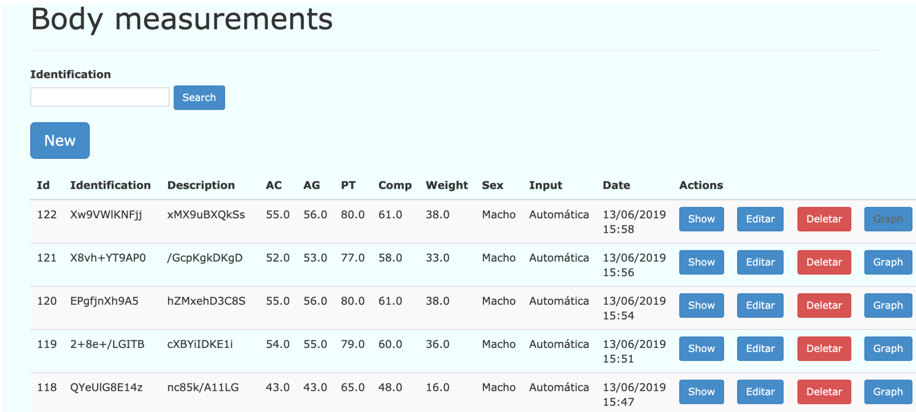

Figure 5: **Sheep body measurements on TMovCapri**

4.2. Mobile device

The mobile device allows you to automate body measurements. Thus, measurements were obtained in sheep. Table 5 shows the comparative statistical data of manual and automatic measurements.

Table 5: Manual and automatic measurements in centimeters

Parameter	Manual measurements			Automatic measurements			Mean relative error (%)
	Average	Standard deviation	Standard error	Average	Standard deviation	Standard error	
WH	57,12	2,89	0,51	53,53	2,90	0,51	7,44%
RH	58,25	2,90	0,51	54,53	3,14	0,55	7,61%
CG	78,09	6,03	1,06	78,50	3,61	0,63	7,19%
BL	60,15	4,04	0,71	59,50	3,04	0,53	6,45%
Weight	36,65	6,20	1,24	36,26	4,38	0,87	13,48%
Depth	29,28	2,07	0,39	31,14	4,39	0,83	10,76%

It is observed that the *average* and *standard deviation* of automatic measurements are close to manual measurements. The *average relative error* was 7.44 % for *WH*, 7.61 % for *RH*, 7.19 % for *CG*, 6.45 % for *BL*, 13.48 % for *Weight* and 10.76 % for *Depth*. The results of *RH* and *BL* are similar to those found by [13] in sheep. Thus, the level of precision observed in field data can be considered adequate to replace the manual measurement system. Table 6 shows the averages with a 95 % confidence interval for manual and automatic measurement.

Table 6: Confidence interval for manual and automatic measurement in centimeters

Parameter	**Manual measurements**	**Automatic measurements**
WH	56,12 a 58,12	52,53 a 54,53
RH	57,25 a 59,25	53,45 a 55,61
CG	76,01 a 80,17	77,25 a 79,78
BL	58,76 a 61,54	58,45 a 60,55
Weight	34,22 a 39,08	34,58 a 37,94
Depth	28,47 a 30,09	29,42 a 32,86

It is noted that the values of the *confidence intervals* of *CG*, *BL* and *Weight*, override the manual and automatic averages, with no significant difference. *WH*, *RH* and *Depth*, on the other hand, have *Automatic measurement* intervals outside the *Manual measurements* range, so there is a statistical difference between these averages.

Table 7 shows the *average accuracy* of automatic measurements in relation to manual measurements and the *paired T* test. It appears that all parameters analyzed show an *average accuracy* above 86.52 % reaching up to 92.56 %. These results are quite expressive, since the animal surpasses the computational device and there is no way to accurately determine the location of the rump height, since the animal is in motion. The values *(p-value)* of *CG*, *BL* and *Weight* have a significance level greater than 5 %, with no significant differences between manual and automatic measurement, while the values of *WH*, *RH* and *Depth* differed statistically.

In some of the measurements performed, it was necessary to repeat the manual measurement at the animal's rump height, due to incorrect posture. This generated noise in the samples, making it difficult to correlate between automatic and manual.

The technical characteristics of the sensors used may have limited the accuracy of the results, but do not make the prototype unfeasible, in addition,

Table 7: Average accuracy of automatic measurements and paired t test

Parameter	**Average accuracy (%)**	**p-value (%)**
WH	92,56 %	5,858 x 10^{-6}
RH	92,39 %	6,90403 x 10^{-6}
CG	92,81 %	0,745
BL	93,55 %	0,466
Weight	86,52 %	0,797
Depth	89,24 %	0,050

WH = Withers Height, RH = Rump Height, CG= Chest Girth, BL = Body Length

the possible improvement in efficiency would occur from the evolution of these sensors or the use of others. The results related to manual and automatic measurements showed that the use of the mobile device becomes feasible. Already [5] evaluated the size and body weight of sheep, with a system that uses a digital camera for image processing, and it is not possible to store measurements in a database, in addition to requiring great computational power. However, TMov-Capri saves the bodily measurements in the database, and enable monitoring of the animal's growth history, and the computer required for the software to operate does not require great processing power. Already, [13] calculating body measurements by image capture and processing, uses various equipment, thus requiring a high cost solution. In addition, the animal remains trapped for measurements, causing stress.

In [6] several body measurements were collected from Travnik Pramenka sheep using the Multiple Linear Regression technique. In the work [3], lambs with at least 50% Santa Inês genetics were used, based on a linear model. Both in [6] and [3] measurements are collected manually, making the process time-consuming and more susceptible to errors, as the animal needs to be in the correct posture.

5. Conclusion

The development and adoption of embedded systems in agriculture has been essential for greater productivity. The use of microcontrollers and sensors contribute to the emergence of ever smaller devices with the ability to obtain information quickly and automated way.

In the proposed computational solution, the TMovCapri software (INPI Registration BR5120118051640-8) and the computational device represent an economically viable alternative to automate the measurement and storage of body measurements. Body measurements performed automatically, allow greater flexibility in the measurements, compared to the traditional method, which requires a costly work with the animal in a correct posture measurement, requiring longer.

In the measurement process with the developed device, there is no need for physical contact with the animal, thus avoiding stress on the animal, which is desirable for the producer aiming at greater productivity in his herd. The device is easy to handle and transport, and is a computational tool of great social applicability, by facilitating the access of producers of sheep.

The set, mobile device and TMovCapri software, represents an innovative and high-impact technological solution, allowing to expand the access of small producers to a technology developed by the academy, demonstrating the importance and scope of research. With this, agility is gained, allowing the breeders to assist in the management of the herd.

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