

Mobile Device and Software for Automating Body Measurements in Sheep and Goats

Abstract

Sheep and goat farming are extremely important activities in national agriculture, an alternative for arid and semi-arid regions, due to their adaptation to adverse conditions. The measurement process is of fundamental importance, since they are inheritable characteristics, withers height, rump height, chest girth, body length and Depth, which reflect on meat production and body development. However, breeders still perform these body measurements on animals, mainly by manual methods. The purpose of this article is to present a computational solution, consisting of a mobile device for automation of data collection in sheep and goats, by means of sensors, as well as software to process and find body measurements. The measurements obtained are stored in a database for purposes of registration and monitoring of the squad. For the proposed solution, the mobile device was built using Arduino technology with sensors, and the software was developed in RubyOnRails. 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, goats, Automation, Software, Embedded System

1. Introduction

Agriculture over the last few decades has performed an important role in regional development in northeastern Brazil. Sheep and goat farming are activities 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.

According to LÔBO et al. (2011) sheep and goat farming has been standing out among the various branches of agribusiness, due to its high profitability and rapid financial turnover. This activity can occupy the space left by other livestock activities and be the main activity within a rural company.

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 (ZHANG et al. (2018)).

Currently, body measurements on animals are performed by manual methods, using the hypometer and measuring tape. This method requires a lot of work with the animal in the correct measurement posture and still demands time. One of the main disadvantages is the impossibility of automatically storing data, as it is not a computational tool. There is a great need to use devices that are easy to handle, applied to the control and management of body measures.

For the success of sheep and goat 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 and goats. 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

The rest of this article is organized as follows. Section 2 provides background on sheep farming and body measures. Section 3 discusses software implementation and device development. Section 4 describes and discusses the results obtained by our proposal. Section 5 provides concluding observations.

2. Theoretical Reference

2.1. *Sheep and goat farming*

Sheep and goat farming, an economic activity explored on all continents, is present in areas under the most diverse climatic and botanical characteristics. However, only in some countries the activity has economic expression, being, in most cases, developed empirically and extensively, with low levels of technology (EMERECIANO NETO et al. (2016)). The consumption of sheep meat is approximately $500g/population/year$, while beef has an average per capita consumption of $(35kg/population/year)$, chicken $(44kg/population/year)$ and pigs $(15kg/population/year)$. The market has grown in large centers, thanks to the slaughter of animals that produce a better quality carcass. With the increasing appreciation and demand, there is an increase in production, which makes

52 promising activity (FERNANDES (2018)).

53 Sheep and goat meat are considered beneficial products that can favor as-
54 pects of human health, and are also suppliers of beneficial fats, in addition to
55 being rich in other nutrients (VASTA and LUCIANO (2011); RIBEIRO et al.
56 (2011)). In this way, the population is adapting to new consumption habits,
57 so that the consumer has a good acceptance of this product, an animal must
58 be produced that meets the market needs and that presents quality standards
59 (SAÑUDO et al. (2012, 2013)).

60 The world herd consists of approximately *1.2 billion* sheep and *1 billion*
61 goats. China concentrates the largest number of sheep heads (*161,315,017*,
62 with 13.41 % of the world herd) and goats (*139,916,096*, with 13.52 % of the
63 world herd) according to the United Nations for Food and Agriculture (FAO,
64 2017) ¹.

65 According to FAO (2017), in the international context, Brazil appears very
66 far from the main countries in the world in terms of sheep numbers (*19th position*
67 - *approximately 18 million heads*) and goats (*22nd position - approximately 9.6*
68 *million heads*). World sheep meat production reached almost 9.5 million tons
69 and approximately 6.2 million tons of goat meat (FAO, 2017).

70 2.2. Body Measurements

71 Measurements are used in animals to evaluate performance, characterize ge-
72 netic groups and estimate live weight (SOWAND and SOBOLA (2008)). Body
73 weight varies according to genotype, sex, age and food system, among others,
74 being of great importance to determine homogeneity of the products to be sold
75 (OSÓRIO and OSÓRIO (2005)). According to CUNHA FILHO et al. (2010),
76 knowledge of body measurements and their correlations with the animal's live
77 weight are strategies commonly used in sheep selection and production pro-
78 grams. Weight and measurements generally correlate positively, and it is ac-

¹FAO - Food and Agriculture Organization of the United Nations. (2017) FaoStat. Avail-
able at: <http://www.fao.org/faostat/en/data/QL>. Accessed on: 02 ago. 2018.

79 ceptable to use them to predict the development of lambs from birth to weaning
80 (KORITIAKI et al. (2012)).

81 Comparative studies of morphological aspects in vivo are important, as they
82 allow comparisons between racial types, weights and feeding systems, being a
83 practical and low-cost method, requiring only good evaluation by a trained pro-
84 fessional. The growth curves can assist in the establishment of specific feeding
85 programs and in the definition of the optimal slaughter age (CARNEIRO et al.
86 (2007)).

87 According to OLIVEIRA et al. (2014), body measurements are grouped ac-
88 cording to the regions of the animals body, in cephalic, trunk and limb measure-
89 ments. The trunk measurements correspond to the *Chest Girth* (CG), which
90 comprises the measurement of the chest girth, passing the measuring tape just
91 after the withers and behind the scapula; *Body Length* (BL) is the measured
92 distance from the scapular-humeral joint to the extremity of the *ischium*; limb
93 measurements are *Withers Height* (WH), vertical distance from the highest
94 point and the ground; *Rump Height* (RH), vertical distance from the highest
95 point of the rump, in the space defined by the spinous process of T5 - T6 over the
96 *sacral tuberosity* of the *ileum*, to the ground. The Fig.1 illustrates the measure-
97 ments of the region of the trunk and limbs in sheep. The number 8 comprises
98 the BL, 11 identifies CG, 16 WH and 18 RH.

99 Measurements are important in sheep production, as they can be used to
100 predict the characteristics of commercial sheep carcasses, are performed on an-
101 imals in vivo, with the purpose of acting on the standardization of the product
102 (PALHARI and C. (2018)). In ZHANG et al. (2018), the sheep body length was
103 used to predict weight, so it is of great importance, as it can reflect production
104 performance.

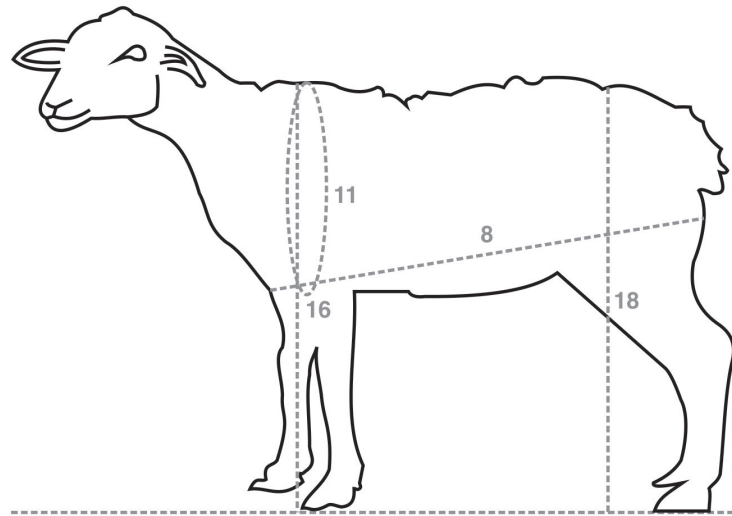


Figure 1: **Body measurements in the trunk and limbs in sheep**

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

105 **3. Materials and Methods**

106 *3.1. Computational System - Overview*

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

111 As for the software with mobile telemetry (*TMovCapri*) for body measure-
 112 ments, it consists of the following program modules:

- 113 • **Serial/USB port reading module** - allows the computer to commu-
 114 nicate with the computing device, in which the captured information is
 115 stored in a file called *"serial_read.txt"*;
- 116 • **Valid reading module** - responsible for reading the file *"serial_read.txt"*.
 117 It analyzes each line, generating the file *"valid_readings.txt"* for each ani-

mal 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.

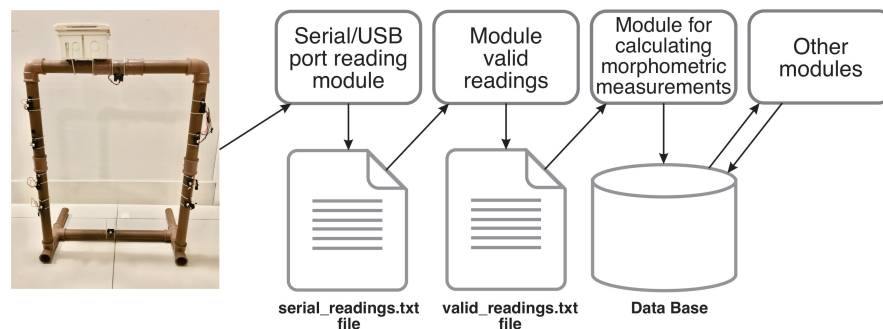


Figure 2: **System proposed and developed**

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 and goats with mobile telemetry (TMovCapri)

3.2.1. Development environment

The TMovCapri was developed on a *Macbook-Pro*, 2.7 GHz Intel Core I5 processor, 8GB of DDR3 memory, which has an operating system installed

138 *Mojave 10.14*. To code the software, the *TextMate* text editor was used, which
139 is also extensible through bundles, and is very much aimed at developers on the
140 MacBook.

141 For coding TMovCapri, *Ruby on Rails* was used, which is based on the Ruby
142 object-oriented language. Ruby on Rails is a framework that allows you to in-
143 crease productivity and facilitate the development of database-oriented applica-
144 tions, since it is possible to create applications based on predefined structures.
145 It was chosen because of some of its qualities: it uses convention instead of
146 configuration, less codes and reduced complexity. The information was stored
147 in the *SQLite* database, written in C language, using little resource, less than
148 500kb of computer memory.

149 3.2.2. *TMovCapri entity and relationship diagram*

150 For the construction of TMovCapri, the *Classic Life Cycle* development
151 methodology was used. The TMovCapri entity and relationship diagram (DER)
152 was created. The Fig.3 graphically represents the relational model of the database.

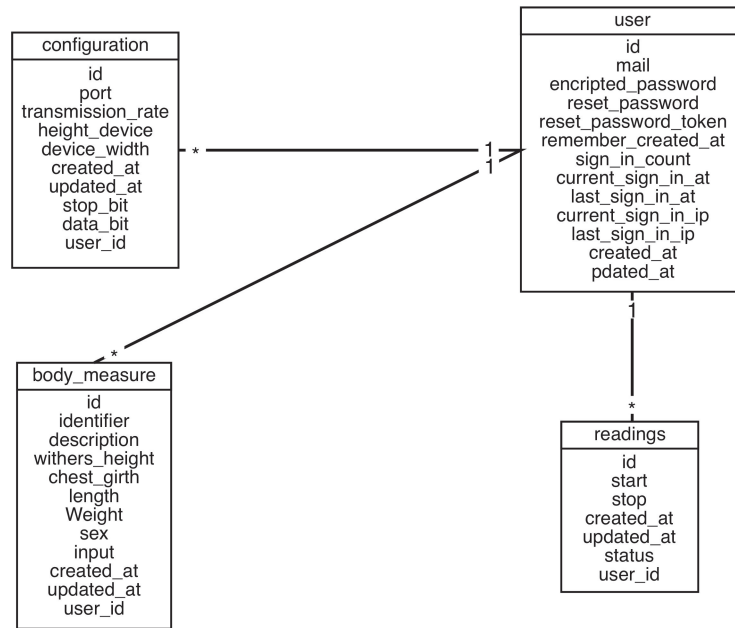


Figure 3: TMovCapri entity and relationship diagram

153 3.2.3. Program module for USB port

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

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

165 In the automatic measurement, each animal overtaking the device, has the
 166 information on the start and end time of this act stored in the *"reading.txt"*

167 file, an identification tag is generated that allows identifying the animal that
 168 has passed the device at the time of measurement where they are recorded in
 169 the readings table of the TMovCapri database.

170 During the measurement process there is no physical contact with the animal.
 171 The Fig.4 illustrates the animal as it passes through the device placed at the
 172 exit of the brete, where the data is captured using the mobile device.



Figure 4: **Capture of data using mobile device**

173 3.2.4. Definition of the regression model for the calculation of body measure- 174 ments

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

178 For validation purposes, measurements were made on 40 Dorper sheep, aged
 179 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.

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

The collected data are stored in electronic spreadsheets and using the *R software*, 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.

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 E_i = *estimated value*, O_i = *measured*

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

202 value and n = number of observations (SANTOS et al. (2014)).

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

203 To validate the model, analysis of variance (ANOVA - dealing with tests
 204 of population means) was used. From this, the p-value $\Pr(>F)$ was obtained,
 205 which represents the probability of the difference observed between treatments
 206 being due to chance and not to the factors studied. Table 3 represents the
 207 ANOVA statistical calculation, the variable y is predicted, and $\hat{y}$ = residual
 208 (error) (WALPOLE et al. (2009)).

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, $\hat{y}$ = 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

209 In the response of the hypothesis tests, a value is compared with the value of
 210 the test power, called p-value (level of significance observed), which represents a

211 lower level of significance where H_0 would be rejected (BARBOSA (2014)). The
 212 p-value is obtained from the sample and the significance level of 5% (denoted as
 213) was fixed before data collection. Table 4 shows the $\Pr(>F)$ obtained from the
 214 analysis of variance and RMSE for the linear and polynomial regression model.

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	4,728e-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-value

215 The p-value calculated above was greater than , implying the non-rejection
 216 of H_0 (equality of variances). Thus, the regression and polynomial models are
 217 significant at the level of 5%. Checking the RMSE values of WH, BL, CG and
 218 weight, we see that in linear regression the values are approximately 17.0 %
 219 for WH, 5.6 % for BL, 12.5 % for CG and 3.5 % for weight, smaller than in
 220 polynomial regression.

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

232 3.3. Mobile device

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

237 The mobile device for automating body measurements in communication
 238 with the WEB software is represented in Fig.5. This device was developed
 239 according to the following components: PVC pipes 40 mm (mm), plastic box,
 240 PVC 90 ° knees of 40 mm, PVC 90 ° 40 mm, Sharp infrared sensor, *Arduino*
 241 *Mega board 2560*, 10 uF capacitor and 0.50 wires.

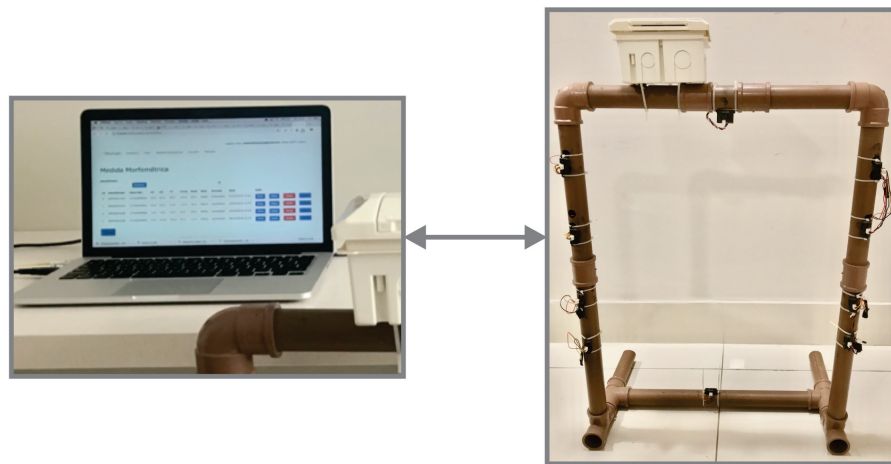


Figure 5: **Computing device in communication with the Web software**

242 Table 5, indicates the sensors and analog ports on the *Arduino Mega 2560*
 243 board, to which they are connected.

Table 5: Sensors connected to the analog ports of the Arduino MEGA 2560

Sensor	Analog port of the Arduino board
A8 (superior)	A8
A7 (inferior)	A7

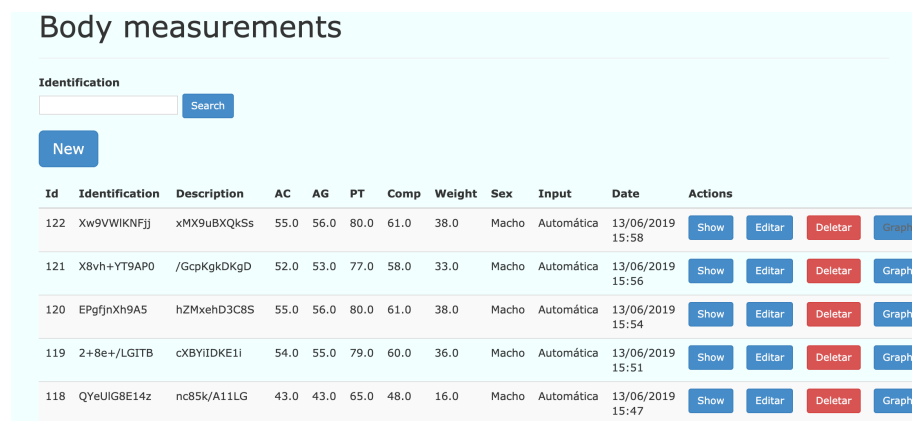
244 The *Arduino Mega 2560* board is located inside a plastic box attached to
 245 the device. To reduce noise, it is necessary to install a 10 uF capacitor between
 246 the ground pin and the voltage input of the sensor, which collects the readings
 247 in voltage format, when finding the animal in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

249 4. Results and discussions

250 4.1. TMovCapri

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

255 To access the TMovCapri the web server needs to be running and the ap-
 256 plication can run on the computer itself, being accessible through the following
 257 URL <http://localhost:3000>. In Fig.6 the body measurements of the animals are
 258 presented, by pressing the menu *Body Measurements*.



Body measurements											
Identification											
Search New											
Id	Identification	Description	AC	AG	PT	Comp	Weight	Sex	Input	Date	Actions
122	Xw9VWIKNFj	xMX9uBXQkSs	55.0	56.0	80.0	61.0	38.0	Macho	Automática	13/06/2019 15:58	Show Editar Deletar Graph
121	X8vh+YT9AP0	/GcpKgakDKgD	52.0	53.0	77.0	58.0	33.0	Macho	Automática	13/06/2019 15:56	Show Editar Deletar Graph
120	EPgfjXh9A5	hZMxehD3C8S	55.0	56.0	80.0	61.0	38.0	Macho	Automática	13/06/2019 15:54	Show Editar Deletar Graph
119	2+8e+/LGITB	cXBYiIDKE1i	54.0	55.0	79.0	60.0	36.0	Macho	Automática	13/06/2019 15:51	Show Editar Deletar Graph
118	QYeUIG8E14z	nc85k/A11LG	43.0	43.0	65.0	48.0	16.0	Macho	Automática	13/06/2019 15:47	Show Editar Deletar Graph

Figure 6: Sheep body measurements on TMovCapri

259 4.2. Mobile device

260 The mobile device allows you to automate body measurements. Thus, mea-
 261 surements were obtained in sheep. Table 6 shows the comparative statistical

262 data of manual and automatic measurements.

Table 6: 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%

263 It is observed that the *average* and *standard deviation* of automatic mea-
 264 surements are close to manual measurements. The *average relative error* was
 265 7.44 % for *WH*, 7.61 % for *RH*, 7.19 % for *CG*, 6.45 % for *BL*, 13.48 % for
 266 *Weight* and 10.76 % for *Depth*. The results of *RH* and *BL* are similar to those
 267 found by ZHANG et al. (2018) in sheep. Thus, the level of precision observed
 268 in field data can be considered adequate to replace the manual measurement
 269 system. Table 7 shows the averages with a 95 % confidence interval for manual
 270 and automatic measurement.

Table 7: 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

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

275 these averages.

276 Table 8 shows the *average accuracy* of automatic measurements in relation
 277 to manual measurements and the *paired T* test. It appears that all parameters
 278 analyzed show an *average accuracy* above 86.52 % reaching up to 92.56 %. These
 279 results are quite expressive, since the animal surpasses the computational device
 280 and there is no way to accurately determine the location of the rump height,
 281 since the animal is in motion. The values (*p-value*) of *CG*, *BL* and *Weight* have
 282 a significance level greater than 5 %, with no significant differences between
 283 manual and automatic measurement, while the values of *WH*, *RH* and *Depth*
 284 differed statistically.

Table 8: Average accuracy of automatic measurements and paired t test

Parameter	Average accuracy (%)	p-value (%)
WH	92,56 %	$5,858 \times 10^{-6}$
RH	92,39 %	$6,90403 \times 10^{-6}$
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

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

289 The technical characteristics of the sensors used may have limited the ac-
 290 curacy of the results, but do not make the prototype unfeasible, in addition,
 291 the possible improvement in efficiency would occur from the evolution of these
 292 sensors or the use of others. The results related to manual and automatic mea-
 293 surements showed that the use of the mobile device becomes feasible. Already
 294 MENESATTI et al. (2014) evaluated the size and body weight of sheep, with a

295 system that uses a digital camera for image processing, and it is not possible to
 296 store measurements in a database, in addition to requiring great computational
 297 power. However, TMovCapri saves the bodily measurements in the database,
 298 and enable monitoring of the animal's growth history, and the computer required
 299 for the software to operate does not require great processing power. Already,
 300 ZHANG et al. (2018) calculating body measurements by image capture and pro-
 301 cessing, uses various equipment, thus requiring a high cost solution. In addition,
 302 the animal remains trapped for measurements, causing stress.

303 5. Conclusion

304 The development and adoption of embedded systems in agriculture has been
 305 essential for greater productivity. The use of microcontrollers and sensors con-
 306 tribute to the emergence of ever smaller devices with the ability to obtain in-
 307 formation quickly and automated way.

308 In the proposed computational solution, the TMovCapri software (INPI Reg-
 309 istration BR5120118051640-8) and the computational device represent an eco-
 310 nomically viable alternative to automate the measurement and storage of body
 311 measurements. Body measurements performed automatically, allow greater flex-
 312 ibility in the measurements, compared to the traditional method, which requires
 313 a costly work with the animal in a correct posture measurement, requiring
 314 longer.

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

320 The set, mobile device and TMovCapri software, represents an innovative
 321 and high-impact technological solution, allowing to expand the access of small
 322 producers to a technology developed by the academy, demonstrating the impor-
 323 tance and scope of research. With this, agility is gained, allowing the breeders

324 to assist in the management of the herd.

325 References

- BARBOSA, M., 2014. Hypothesis and application test
- CARNEIRO, P.L.S., MALHADO, C.H.M., SOUZA J UNIOR, A.A.O., SILVA, A.G.S., SANTOS, F.N., SANTOS, P.F., PAIVA, S.R., 2007. Weight development and phenotypic diversity among crosses of Dorper sheep with local breeds. *Pesquisa Agropecuaria Brasileira*, Brasilia v.42, n.7, 991–998,.
- CUNHA FILHO, L., REGO, F., F.A.B., B.J., STERZA, F., OKANO, W., TRAPP, S., 2010. Body weight prediction from body measurements in Texel sheep. *unipar's veterinary science and zoology archives*.
- EMERECIANO NETO, J.V., DIFANTE, G.d.S., FERNANDES, L., COSTA, M.G., ARA' UJO, C.d., LUNA, A.A., 2016. Economic evaluation of the production of sheep meat in cultivated pastures URL: http://scholar.googleusercontent.com/scholar?q=cache:AgGb_jun0-gJ:scholar.google.com/baixoniveisdetecnologianaovinocultura&hl=pt-BR&as_sdt=0,5&as_ylo=2017.
- FERNANDES, J.B., 2018. Quality of sheep carcass and meat in con-finishing fed with different levels of inclusion of jurema hay preta (*tenuifoliar mimosa* (wild.) (porir.)). Federal University of Campinas Grande, Health and Rural Technology Center. Campina Grande, 72.
- KORITIAKI, N., RIBEIRO, E.A., JUNIOR, F., F., S., L., C., CONSTANTINO, C., 2012. Prediction of live weight from body measurements in lambs Santa Inês. *Synergismus scyentifica UTFPR*, White duck.
- L'OBO, R.N.B., PEREIRA, I.D.C., FAC' O, O., MCMANUS, C.M., 2011. Eco-nomic values for production traits of morada nova meat sheep in a pasture based production system in semi-arid brazil. *Small Ruminant Research* 96, 93–100. doi:10.1016/j.smallrumres.2011.01.009.
- MENESATTI, P., COSTA, C., ANTONUCCI, F., STERI, R., PALLOTTINO, F., CATILLO, G., G., 2014. A low-cost stereovision system to estimate size and weight of live sheep. *Computers and Electronics in Agriculture* v.103, 33–38,.
- OLIVEIRA, D., OLIVEIRA, C.A.P., MARTINS, E., VARGAS J'UNIOR, F., FERREIRA, M., SENO, L., OLIVEIRA, J., SASA, A., 2014. Characterization morphostructural morphology of females and young males of sheep naturalized from the south of Mato Grosso. "swampland" grossenses. *Agricultural Sciences Magazine*, Londrina v. 35, no. two, 973–986,.
- YOU'ORIO, J., OS'ORIO, M., 2005. Sheep meat production: Techniques of "in vivo" and carcass evaluation. 2nd ed., Federal University of Pelotas. Ed. Universit'aria, Pelotas.
- PALHARI, N., C., 2018. Relationship between in vivo morphometry and characteristics of commercial sheep carcasses. Dissertation (Master in Animal Science).
- RIBEIRO, C., OLIVEIRA, D., JUCHEM, S., 2011. Fatty acid profile of meat and milk from small ruminants: a review. *Revista Brasileira de Zootecnia* v.40, 121–137, . Suplemento especial.
- SANTOS, W.O., SILVA, K.D., COELHO, D.C., SILVA, K., SOBRINHO, J., SILVA, P., BATISTA, R., 2014. Spatial and temporal variability of pre-precipitations for the micro-region of pau dos ferro-m. *Brazilian Magazine of Geography and Physics* v. 07, no. 3, 434-441.
- SA'NUDO, C., M.M., C., E., M., J.L., O.C., DELFA, B., JIM'ENEZ, B., A.A.M., J., A., H.I., OLIVEIRA, I., CILLA, I., 2012. Carcass characteristics and instrumental meat quality of suckling kids and lambs. *Spanish Journal of Agricultural Research* 10, 690–700.

SAÑUDO, C., MUELA, E., CAMPO, M., 2013. Key factors involved in lamb quality from farm to fork in europe. *Journal of integrative agriculture* 12, 1919–30.

SOWAND, O., SOBOLA, O., 2008. Body measurements of west african dwarf sheep as parameters for estimation of live weight. *Tropical Animal Health and Production* v.40, 433–439.

VASTA, V., LUCIANO, G., 2011. The effects of dietary consumption of plants secondary compounds on small ruminants' products quality. *Small Ruminant Research* doi:10.1016/j.smallrumres.2011.09.035.

WALPOLE, R., MYERS, R., MYERS, S., YE, K., 2009. Probability and Statistics for engineering and science. Pearson Prentice Hall, São Paulo.

ZHANG, A.L., WU, B.P., WUYUN, C.T., JIANG, D.X., XUAN, E.C., MA, F.Y., 2018. Algorithm of sheep body dimension measurement and its applications based on image analysis. *Computers and Electronics in Agriculture* 153, 33–45. doi:10.1016/j.compag.2018.07.033.

- 379 SOWAND, O., SOBOLA, O., 2008. Body measurements of west african dwarf
380 sheep as parameters for estimation of live weight. *Tropical Animal Health*
381 and Production v.40, 433–439.
- 382 VASTA, V., LUCIANO, G., 2011. The effects of dietary consumption of plants
383 secondary compounds on small ruminants' products quality. *Small Ruminant*
384 *Research* doi:10.1016/j.smallrumres.2011.09.035.
- 385 WALPOLE, R., MYERS, R., MYERS, S., YE, K., 2009. Probabilidade e Es-
386 tatística para engenharia e ciências. Pearson Prentice Hall, São Paulo.
- 387 ZHANG, A.L., WU, B.P., WUYUN, C.T., JIANG, D.X., XUAN, E.C., MA,
388 F.Y., 2018. Algorithm of sheep body dimension measurement and its appli-
389 cations based on image analysis. *Computers and Electronics in Agriculture*
390 153, 33–45. doi:10.1016/j.compag.2018.07.033.