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3D Scanning Methodology to Characterize Surface Area and Envelope Volume of Poultry, Livestock, and Equine

Emile Joseph Koury

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3D scanning methodology to characterize surface area and envelope volume of poultry, livestock, and equine

By
Emile Joseph Koury, III

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Mississippi State, Mississippi

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3D scanning methodology to characterize surface area and envelope volume of poultry, livestock, and equine

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Broiler birds have drastically increased in size over the past few decades through improvements in genetic selection. Physical measurements such as surface area, volume and physical dimensions are needed information in the construction of animal facilities and developing management guidelines. The objective of this study was to develop a three-dimensional scanning methodology to characterize surface area and envelope volume of poultry, livestock, and equine using a commercially available 3D digitizer system. The digitizing system used phase shift moiré to capture images of three test cylinders, four fiberglass animal models, and a live broiler bird. These images were spliced into physical models using image processing software. System accuracy (< 2%) was verified with cylinder models. Recommended camera orientations and placements were established with each species by the use of fiberglass models. The methods will have to be fine-tuned for live animals as observed in the live broiler test.
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# TABLE OF CONTENTS

ACKNOWLEDGEMENTS ........................................................................................................ ii

LIST OF TABLES ................................................................................................................ v

LIST OF FIGURES ............................................................................................................ vi

CHAPTER

I. INTRODUCTION .............................................................................................................1

   Means of Measurement .............................................................................................. 2
   Objective .................................................................................................................... 4

II. MATERIALS AND METHODS ...................................................................................5

   Scanning System and Software ................................................................................ 5
   Cylinder Models ......................................................................................................... 7
   Fiberglass Models ...................................................................................................... 8
   Live Chicken Model ................................................................................................. 9
   Pre-Acquisition Setup ............................................................................................. 10
   Image Acquisition .................................................................................................... 12
   Preprocessing Data ................................................................................................. 14
   Process & Post Process Data ................................................................................... 16
   Construction of Model ............................................................................................ 17

III. RESULTS AND DISCUSSION ................................................................................. 22

   Cylinder Models ..................................................................................................... 22
   Fiberglass Models ................................................................................................. 26
   Live Broiler Model ................................................................................................. 32
   System Limitations ................................................................................................. 36
   Conclusion ............................................................................................................. 37

REFERENCES ................................................................................................................ 38
LIST OF TABLES

3.1 Physical calculations vs Geomagic calculations ................................................25
3.2 Fiberglass model surface area and volume calculations ........................................32
LIST OF FIGURES

2.1 Basic setup with digitizer on adjustable stand ...........................................5
2.2 Sheet metal cylinder models ........................................................................8
2.3 Cowpainters, LLC fiberglass models ...........................................................9
2.4 Live Broiler Chicken ................................................................................10
2.5 Two basic camera orientations .................................................................11
2.6 Control Center .........................................................................................13
2.7 Raw Images of Cylinder ..........................................................................13
2.8 Grayscale Images of Medium Cylinder ...................................................14
2.9 Grayscale Image of Live Bird ..................................................................15
2.10 Fringe Projection on Fiberglass Chicken ................................................15
2.11 Pseudo-color Images of the Medium Cylinder .......................................17
2.12 Manual Registration Process ................................................................18
2.13 Geomagic Images of Fiberglass Chicken ................................................19
2.14 Complete 3D Model ...............................................................................20
3.1 Orientation in Cardinal Direction .............................................................23
3.2 Completed Cylinder Models ......................................................................24
3.3 Fiberglass Chicken Final Camera Setup ................................................26
3.4 Fiberglass Pig Final Camera Setup ........................................................27
3.5 Fiberglass Cow Final Camera Setup .......................................................28
3.6 Second Final Camera Setup for Fiberglass Cow .......................................29
<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.7</td>
<td>Fiberglass Horse Final Camera Setup</td>
<td>30</td>
</tr>
<tr>
<td>3.8</td>
<td>Fiberglass Horse Final Camera Setup</td>
<td>30</td>
</tr>
<tr>
<td>3.9</td>
<td>Completed 3D Fiberglass Models</td>
<td>31</td>
</tr>
<tr>
<td>3.10</td>
<td>Initial Live Broiler Setup</td>
<td>33</td>
</tr>
<tr>
<td>3.11</td>
<td>Fringe Projection on Live Broiler</td>
<td>33</td>
</tr>
<tr>
<td>3.12</td>
<td>Grayscale images of Live Broiler</td>
<td>34</td>
</tr>
<tr>
<td>3.13</td>
<td>Pseudo-color Images of Live Broiler</td>
<td>35</td>
</tr>
<tr>
<td>3.14</td>
<td>Completed 3D Model of Live Broiler</td>
<td>35</td>
</tr>
<tr>
<td>3.15</td>
<td>Example of Void Spaces</td>
<td>36</td>
</tr>
</tbody>
</table>
INTRODUCTION

Broiler birds have drastically increased in size over the past few decades through improvements in genetic selection. Physical measurements such as surface area, volume and physical dimensions are needed information in the construction of animal facilities and developing management guidelines. Standards data for livestock and poultry dimensions date back 30 years (ASAE D321.2 MAR1985). There is no physical information for poultry, only weight by day of age.

Bird size is a determining factor on ventilation and evaporative cooling methods employed to maintain a comfortable thermal environment. Heat and mass calculations to determine ventilation periods rely on the surface area of the birds. The surface area of the animal is the interface for skin convective, radiant and evaporative heat loss (Berman 2003). Extreme temperatures experienced during summer months can cause excessive maintenance expenses in order to upkeep ideal house conditions. Incorrect estimations of surface area can produce excessive energy waste on days with harsh static air temperature.

Body dimensions are important in determining minimum space allocations for livestock, especially when they are individually confined (Hurnik and Lewis 1991). Insufficient space for physiological activities can result in poor animal welfare compromising economic gains. The value and condition of a meat animal depends on the
conformation and composition of its body (Frost et al. 1997). Livestock dimensions are also taken by physical means or assessed visually as a judgment of body weight. Feed ratios are determined with these two factors; weight and size. The significance of modern day dimensions for poultry and livestock will boost facility efficiency and promote maximum economic gains for the producer.

**Means of Measurement**

Body surface area has been used for various applications. A known surface area for an animal can predict live weight, space allowance and heat exchange. The calculation of surface area either involves direct measurement or the use of numerous predictive equations. Documented methods for gathering direct measurements for surface area date back to the 19th century. Before the help of computers, these methods required a hands on approach. These methods of obtaining animal surface area involved a great deal of handling and time. Hogan and Skouby (1923) wanted to find the surface area of livestock and swine. They prepared a mold out of the live animal by the use of a paper mache technique. This mold was made in four groups then cut off the animal and traced out. The cut-outs from the tracings were weighed and surface area was determined by the weight of paper per square centimeter. Their slaughtered technique involved tracing the outline of the hide from one side of the animal’s body. Area was determined by the measurement of rectangles and triangles inside the outline. The amount of time taken for each method was not reported.

Recent research on surface area measurement involves image analysis and 3D measurement. These methods provide a non-invasive means to obtain parameters and are less time consuming. The use of images refrained from direct harm to the animal. The
physical handing in the use of imagery is at a minimum. 2D analysis involves pixel
calculation in a given area while 3D analysis creates an actual model representation of the
animal with the use of computer software.

Mollah et al. (2010) achieved body weight estimations by image analysis of two-
dimensional captures. Broiler chickens were individually placed in a pen and a centered
aligned digital camera captured an overhead image. The summation of surface-area
pixels for each image was applied to the bird’s weight taken conventionally. Weight to
pixel correlation was determined and a linear regression model was implemented.
Prediction of body weight by pixel analysis had a higher error percentage on larger birds.

Yanagi Júnior et al. (2011) used a three-dimensional approach while
incorporating the moiré technique for their evaluation in surface area calculation
procedure. A single shot digital camera captured the image while image processing tools
generated a three-dimensional image of each chicken. The conventional method was also
used for a group of chickens for validation and calibration of their moiré technique. This
procedure of measurement exhibited an error close to 5%.

Several other techniques involving image analysis for animals exist to determine
shape characteristics. Another technique used for geometry evaluation was stereo
photogrammetry. Wu et al. (2004) set up a system to capture three-dimensional shapes of
pigs. Six high resolution cameras captured a top, side and rear stereo images of a pig.
Construction software matched the six images and created a three-dimension model. Wu
et al. system of capture produced an accurate means to extract the shape of a live pig and
create a three-dimensional model. The work of Wu et al. (2004) was incorporated for
shape measurement by McFarlane et al. (2005) to build up on method developments for shape measurements of live pigs.

Previous studies were successful in creating a less destructive method for calculating body measurements of animals. The amount of time for image capture and animal handling is still a concern for improvement. Optical approaches have rapidly increased in the last decade dealing with physical characterization. Present research can combine all previous techniques into one system of methods. This refined optical technique was found available in a commercially developed system.

Objective

The objective of this study was to develop a three-dimensional scanning methodology to characterize surface area and envelope volume of poultry, livestock, and equine using a commercially available 3D digitizer system.

Sub objectives include:

- Verification of digitizer system accuracy using a range of cylinder models
- Develop recommendations for digitizer camera placement for each species using fiberglass models
- Test methodology on a broiler chicken to understand live animal issues
MATERIALS AND METHODS

Scanning System and Software

A 3D digitizer system (3D MegaCapturor Body Digitizer, Creaform, Newark, DE) was chosen to capture images from live animals because of the rapid image capture rate (< 1 s), adjustability of digitizer positions and field of view, portability, and commercial availability. The system consisted of four digitizer cameras (up to six cameras can be used in sequence) on adjustable 1.6 m stands (Fig. 2.1), firewire and serial communication cables, a control computer, and system software.

Figure 2.1  Basic setup with digitizer on adjustable stand.
The digitizers were operated with an acquisition software program (InSpeck Fringe Acquisition and Processing Software (FAPS) v7.5, Creaform, Newark, DE). Serial cables were connected from each digitizer to a multiplexer that was linked to the control computer for system communication. FireWire cables were connected from each camera into a FireWire hub for image transfer. A one to two camera operation should run a direct connection to the control computer while a three to six camera operation required the use of the serial multiplexer and FireWire bus. The power supply can be switched depending on local electricity distribution (120 or 240 VAC, 60 or 50 Hz). The control computer was a 1 TB desktop (h8-1124, Hewlett Packard, Palo Alto, CA) with a dual serial card and dual FireWire card installed.

The system was able to acquire texture and geometry from a given model using phase shifted moiré and active optical triangulation (Inspeck User’s Guide, 2005) in an optical measurement system. Triangulation uses parallax points to reference distance in the image plane. By knowing the position of each reference point, it is possible to compute the z-coordinate of the points of the surface (Sciammarella et al. 2010). Fringe projection is displaying a pattern consisting of dark and light stripes to determine surface curvature by arbitrating the displacement of each stripe. The moiré technique superimposes the fringe gradients and applies a phase shift to one of the gradients retrieving surface shape of the object. The moiré pattern was represented as the projected fringe on the object. This pattern shifts slightly during an acquisition to gather multiple images. These images are combined as one to detect deformation of the fringe which results in the determination of a contour.
Model surfaces must diffuse light back to the 3D digitizers. Surfaces for capture should not be reflective or transparent. The fringe pattern that is projected on the model is dynamic during acquisition which allowed the digitizer to retrieve geometry and color information.

Geomagic Wrap (3D Systems, Rock Hill, SC) imported the 3D point cloud images created in FAPS to construct the final model for analysis. This software was able to transform the point cloud images into a 3D polygon model.

**Cylinder Models**

To verify the digitizer’s system accuracy, a set of three cylinders were constructed to represent the physical ranges of poultry, livestock and equine (Fig. 2.2). The cylinders were made of sheet metal wrapped around plywood end caps. The large cylinder was 2.13 m in length with a diameter of 8.31 m and represented a cow or horse. The medium cylinder was 1.07 m in length with a diameter of 5.60 m and represented a pig. The small cylinder was 0.23 m in length with a diameter of 0.15 m representing the size of a broiler chicken. The surface area of each cylinder with diameter \(d\) was calculated with equation 2.1. The volume of each cylinder with diameter \(d\) was calculated with equation 2.2.

\[
Surface\ Area = 2\pi \left(\frac{d}{2}\right)^2 + 2\pi \left(\frac{d}{2}\right) h \quad \text{Equation (2.1)}
\]

\[
Volume = \pi \left(\frac{d}{2}\right)^2 h \quad \text{Equation (2.2)}
\]
Three cylinder models were created out of sheet metal to represent the various sizes of animals:

a) Large for a horse or cow
b) Medium for a pig
c) Small for a broiler chicken.

**Fiberglass Models**

To develop the image capture methodology needed for each species, a set of four fiberglass models depicting characteristic geometry of adult animals were purchased (Fig. 2.3). The models included a dairy cow (#167, Cowpainters, LLC, Chicago, IL), horse (#732, Cowpainters, LLC, Chicago, IL), pig (#172, Cowpainters, LLC, Chicago, IL), and chicken (#341, Cowpainters, LLC, Chicago, IL) in the standing position. The large animals were placed on casters for ease of movement. The chicken was placed on a platform during scanning.
Figure 2.3    Cowpainters, LLC fiberglass models

Four fiberglass models used to represent each animal species in the standing position
a) Dairy cow  
b) Horse  
c) Pig  
d) Chicken

**Live Chicken Model**

A live broiler chicken, housed at the USDA ARS Poultry Research Unit, was used
to create a 3D model with the previously developed methodology (Fig. 2.4). This
exercise would allow the team to adapt the methodology to account for issues of a live
animal and differences in surface textures.
Pre-Acquisition Setup

Placement of digitizers was the most crucial step in image acquisition and was managed in the acquisition control center of the FAPS software. To begin the process, the object of interest was placed in the center of four digitizer cameras (Fig. 2.5). The digitizers were initially placed with the long and short axis of the model at the cardinal coordinates. Images were also taken with the model rotated 45° and further adjusted as the size of the models increased. For the longer models, the digitizers could be rotated from a vertical to a horizontal orientation to increase the field of view. Efforts were made to include an overlapping region between images to improve the accuracy of the merging process.

Each digitizer was fastened to an adjustable stand and placed at a minimum distance of 1 m from the nearest surface (Inspeck User’s Guide, 2005). Digitizer height
and distance from the model surface was adjusted by observing the model in the FAPS software viewfinder and correctly aligning the model to fit in the full view area. Blind spots are generated by underlying areas and surfaces blocked by forward model surfaces. These were minimized by observing the positions of limbs facing the camera and adjusting for underlying areas. Effort was taken to minimize these hidden areas using the digitizer fringe projections to adjust camera placement. A final adjustment was made using the eight parallax points that each digitizer projected within the fringe pattern. At least two of the eight parallax points needed to be visible on the model surface for an accurate image capture.

Figure 2.5  Two basic camera orientations

a) Face-on and
b) 45° offset, were used for initial evaluation

The second crucial step during setup was setting the lighting levels. Lighting conditions in the scanning room had to be controlled because it affects the fringe contrast. The ideal lighting scenario is minimal external light. In some instances, external light could not be controlled and efforts were made to adjust intensity levels in the digitizers.
Using the FAPS acquisition control center, each digitizer’s fringe intensity was adjusted (given as a percentage) to maximize the quality of the image. The surface of the model or live animal can also affect the fringe intensity. The objective of intensity adjustment is to avoid fringe saturation. Saturation in the data image will result in incomplete or major disturbances in image quality. Most settings were similar for each digitizer unless a digitizer was capturing a larger surface area than the others.

Though digitizer placement and lighting were the major concerns in image acquisition quality, movement of a live animal also caused image distortions. Micro-movements such as a slight head flinch were deemed acceptable in an image but larger movements such as body rotations had to be retaken. Efforts were made to accustom the live animal to the fringe projections from multiple digitizers before taking an image. This seemed to minimize movements. Image distortions were identified in the first phase of image processing and resulted in a second image capture sequence.

**Image Acquisition**

The capture sequence was executed in two ways. All digitizers were shot in a series by executing the **ALL** function in the acquisition control center (Fig. 2.6). Each camera has a corresponding button, **1-4**, that activates a single camera for capture. The images are available as raw data (Fig. 2.7) and are saved as a whole sequence or saved as an individual image.
Figure 2.6  Control Center

Camera settings were adjusted in the acquisition control center accessed in FAPS

Figure 2.7  Raw Images of Cylinder

Four raw images of the medium cylinder sequenced with cameras in the cardinal directions
a) Left
b) Right
c) Front
d) Rear
Preprocessing Data

Following the image acquisition sequences, the “preprocess” option was enabled in the FAPS acquisition center to preprocess the images. Each image was processed individually in sequence order. Inspeck FAPS auto detects the location of the parallax points that were projected on the model. The computed phase function appeared as grayscale images (Fig. 2.8). These results determine if an acquisition is usable to extract 3D data. Distortions by movement, light intensity or distance appeared as an irregularity (Fig. 2.9). Interpretation of this information has been gained by experience. The “select interest area” tool in FAPS was used to determine the boundaries of the image interest area. This process was completed manually by using the computer mouse to trace a white line around the model using a series of left clicks (Fig. 2.10). The select interest area process eliminated unnecessary background noise before post-processing. Once the desired interest area has been selected, image processing can begin.

![Grayscale Images of Medium Cylinder](image)

**Figure 2.8** Grayscale Images of Medium Cylinder

Medium cylinder grayscale images used to determine image quality
a) Left
b) Right
c) Front
d) Rear
Figure 2.9  Grayscale Image of Live Bird

The rear of a bird showing an example of a distortion (red rectangle) caused by interference

Figure 2.10  Fringe Projection on Fiberglass Chicken

Image of the fiberglass chicken with fringe projection. The interest area selection was highlighted with a white line
Process & Post Process Data

The “process” tool within FAPS displayed the area of interest in a pseudo-color image (Fig. 2.11). This process verified that the software was giving the image a correct depth perception. A discontinuity in the color diagram illustrated an incorrect depth perception captured by the digitizer. The color red represents areas closer to the digitizer. The furthest areas are represented in blue, while green shades fills the middle areas. Discontinuities in depth were fixed by enclosing the discontinuous area then filling the zone with the fill area command. The push or pull option adjusted the area to reflect the correct position. The final pseudo-colored image would show the corrected gradient of colors.

The “post processing” tool in FAPS transformed the edited pseudo-colored data into a 3D image. After the image has been post processed, the 3D plot option became available to verify that the image was usable for the construction of a 3D model. When an image was exported, a sampling value of 1 sample over 2 was chosen. This value indicated a sampling of one point over every 2 acquired data points in each lateral axis (Inspeck FAPS User’s Guide, 2005).
Medium Cylinder after preprocessing to examine for discontinuities
a) Left
b) Right
c) Front
d) Rear

**Construction of Model**

The processed images exported from FAPS were imported into Geomagic Wrap (3D Systems, Rock Hill, SC) for 3D construction and analysis. This modeling software contains numerous operations and editing tools that were used to create a 3D polygon model from point cloud data. These point clouds were developed into polygon surfaces.

Manual registration was selected in Geomagic to begin the process of creating the 3D models. The images were roughly registered by defining overlapping points on surfaces. This was accomplished by viewing two selected images simultaneously and defining points on each surface to merge into one group (Fig. 2.12). The remaining images were selected and registered by the same process. The efforts made in the initial image overlap in the FAPS acquisition process made the manual registration process less complicated.
Figure 2.12  Manual Registration Process

The manual registration process was performed in Geomagic. The user defined three mirroring points on two images to be stitched together.

The global registration tool in Geomagic refined the registered points on the surfaces that compromise a single object through an iteration process. The control group allows various controls to be set. The process of global registration stops when one of these controls is reached. These controls are automatically set by Geomagic, but can be changed if proper results are not achieved. Global registration can be reapplied to the model if the image lineup is still in disarray. The controls were only adjusted when the registration of images were noticed to be loosely joined at the seams.

The completion of the global registration process resulted in a combined object of registered images (Fig. 2.13a). Then the “combine point objects” operation was selected to create a single point object. A mesh was formed out of the point cloud data by executing the “wrap” command and transformed the single point object into a polygon object (Fig. 2.13b).
At this point, the model had rough surfaces in some places and depending on the quality of data, incomplete areas (holes) were present. The “polygons” tab contained the tools for editing the surface. The “fill holes” box gives the options of “fill all” or “fill single” operations. The fill single command only filled holes selected by the mouse. This command was useful when the incomplete areas were small. The fill all command first analyzes the model for holes. Each hole was outlined in red. When “apply” was pressed, all active holes were filled on the polygon object with one of the three types of mesh fillings. Curvature mesh filling created a mesh patch to match the curvature of the surrounding mesh. Tangent mesh filling created the same mesh curvature, but with a more tapering curve. Flat mesh filling resulted in a flat mesh patch. The type of mesh filling was decided by the researcher.

Other settings used in the fill single command were complete fill, partial fill or bridge fill. Complete fill covered the entire opening of the mesh hole. Partial fill only
filled a portion of the hole by selecting two points to create a boundary line. A bridge fill would build a bridge of mesh across a hole dividing it into separate smaller mesh holes. Bridging gaps allowed complex holes to be more manageable in the editing process. An excessively large area of incomplete mesh needs to be filled piece by piece. A large fill area can result in a deformation in shape contour resulting in insignificant representation of true curvature. By filling in holes with bridges and small area fills, the final model resulted in a better depiction of the original curvature.

The last operation in Geomagic was the “mesh doctor” command. This command cleans up all of the edits performed and fixes abnormal mesh surfaces. Analysis of the full model mesh was executed and the portions of mesh that needed repair were highlighted in red. The analysis group consisted of these problems: non-manifold edges, self-intersections, highly-creased edges, spikes, small components and small holes. Auto-repair was enabled to correct every issue when OK was pressed. The 3D model was complete at this stage (Fig. 2.14).

Figure 2.14 Complete 3D Model

Three views of a complete 3D surface model for the fiberglass chicken model
Mathematical analysis of the completed model was performed in Geomagic. The two body geometries in concern are the surface area and volume. In the analysis box of Geomagic, surface area and volume were calculated. The equation to find a volume with an irregular surface is defined in Equation 2.3.

\[ V = \iiint f(x, y, z) \, dV \]  \hspace{1cm} \text{(Equation 2.3)}
RESULTS AND DISCUSSION

Cylinder Models

All three cylinder models (small, medium, and large) were scanned with two digitizer orientations to validate system accuracy. Digitizers placed in the Cardinal directions provided sufficient images for model development (Fig. 3.1) Model surfaces were determined with the Geomagic software (Fig. 3.2). Physical and model measurements are compared in Table 3.1 for each cylinder. The four images taken for each cylinder provided sufficient data to construct a 3D model. Blind spots only occurred directly on the top and bottom edge of each model. Editing tools which included the tangent mesh using the single fill were able to fill the empty holes left in the model. Differences in the physical measurements and the 3D models were small (< 2%).

As the cylinder models got larger, the surface error decreased. This trend is due to the larger standard error because of smaller size. The stitching process was the same for each cylinder. The volume error did not show the same downward trend. The medium cylinder had a higher relative difference between the model and shape. A possibility of this increase was an unnoticed underlay in model creation, which caused unnecessary area being filled that took away from space enclosure.
Figure 3.1  Orientation in Cardinal Direction

Digitizers placed in the Cardinal direction for the medium cylinder
Figure 3.2  Completed Cylinder Models

Image shows the 3D Geomagic Cylinder models
a) Large  
b) Medium  
c) Small
Table 3.1  Physical calculations vs Geomagic calculations

<table>
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<th>Cylinder</th>
<th>Surface Area</th>
<th></th>
<th>Volume</th>
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<td>Measured m²</td>
<td>Model m²</td>
<td>Difference %</td>
<td>Measured m³</td>
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<td>5.3919</td>
<td>5.3976</td>
<td>0.05</td>
<td>0.80279</td>
</tr>
</tbody>
</table>

*Table presents the calculated numbers of the three cylinders.
**Fiberglass Models**

All four fiberglass models were initially scanned with digitizer cameras in the Cardinal directions; however, each animal had unique features that required the adjustment of the camera placements.

The chicken model was initially scanned with three cameras 120° apart to reduce the number of images to process. However, it was determined that three images provided insufficient data to complete the model. The three images captured most of the body but hidden features between the legs prevented the software from meshing the legs completely. The fourth camera was added to the original Cardinal directions to fill in the excess blind spots. The face-on camera setup was chosen over the 45° offset for most detail capture considering the model’s posture (Fig. 3.3).

![Fiberglass Chicken Final Camera Setup](image-url)
The pig required the cameras to be placed in the 45° positions to capture features. Cameras were initially placed at the 45° angle (Fig. 3.4) then adjusted in the image viewer in FAPS for blind spot coverage. The pig’s round back left little coverage on top to create a blind spot. Details in facial features and the inner legs were an importance.

Figure 3.4  Fiberglass Pig Final Camera Setup

The cow was double the size of the pig and multiple sequences were shot to figure out the best procedure in capturing images. The four cameras were initially placed in the Cardinal directions (Fig. 3.5). The front and rear cameras were set vertically on stands covering these detailed areas. The left and right side cameras were placed in the horizontal position to capture the full length of the cow. The cow’s back comprised a large area that the four cameras could not view. This required a fifth camera location to capture an image from above (Fig. 3.6). After the first sequence of four images were
shot, a second sequence captured the top view. Because the cow had an udder, there were fine details missed due to blind areas. The complex structure of the udder resulted in a misrepresented form displayed in the model. Two side images will not suffice a complete depiction of the udder. An additional camera placed underneath the cow, digitizing the full front side of the udder, would result in a more accurate udder detail.

Figure 3.5  Fiberglass Cow Final Camera Setup
This was the final setup for the first acquisition sequence of the cow
The large cylinder methodology was initially used for the horse. The horse’s body geometry surpassed the cow in size and height. Difficulties arose on the first analysis of images. The two side horizontal cameras were extended out of range and were not able to capture the correct details needed. The front face camera depth perception was inaccurate due to an extreme distance from nose to chest. The rear camera was the only camera in the first sequence to provide a quality image. After further analysis, a total of two sequences were shot in order to capture the horse. Two cameras were placed on each side for the first sequence (Fig. 3.7). The second sequence consisted of a front chest, face, backside and top image (Fig. 3.8). A total of eight images were used to construct an accurate 3D model of the horse.
Figure 3.7   Fiberglass Horse Final Camera Setup

The final camera setup sequence for horse in the first sequence

Figure 3.8   Fiberglass Horse Final Camera Setup

The final second camera setup sequence included a top, chest and head shot of the horse.
After properly placing the cameras for image acquisition, 3D surface models were constructed for each fiberglass model (Fig. 3.9). Table 3.2 illustrates the surface areas and volumes calculated from the 3D surface models. The exact surface area and volume of each fiberglass model was unknown. In the cylinder test to verify the accuracy of the 3D scanning system, minimal percent difference demonstrated a small error in calculation for varying sizes. This result justifies the values given for each fiberglass model are considered to have an acceptable level of accuracy.

![Image of completed 3D fiberglass models](image)

**Figure 3.9** Completed 3D Fiberglass Models

The four completed fiberglass models in Geomagic
a) Dairy cow
b) Pig
c) Chicken
d) Horse
Table 3.2  Fiberglass model surface area and volume calculations

<table>
<thead>
<tr>
<th></th>
<th>Surface Area m²</th>
<th>Volume m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horse</td>
<td>6.03</td>
<td>0.58</td>
</tr>
<tr>
<td>Cow</td>
<td>5.38</td>
<td>0.59</td>
</tr>
<tr>
<td>Pig</td>
<td>2.38</td>
<td>0.19</td>
</tr>
<tr>
<td>Chicken</td>
<td>0.22</td>
<td>0.01</td>
</tr>
</tbody>
</table>

The exact surface area and volume of each fiberglass model is unknown. In the preceding test to verify the accuracy of the 3D scanning system, minimal percent difference demonstrated a small error of calculation for varying size models. Referencing to this test, the numbers provided for each fiberglass model represents an accurate physical calculation of surface area and volume.

**Live Broiler Model**

The process in finding body geometry for the fiberglass chicken set the initial methods used with the live chicken (Fig. 3.10). Numerous sequences were shot due to excessive movement and unwanted body posture. The ideal position was an upright stance with legs spaced apart. Shooting angles could not be determined accurately since the bird moved from the original position. Sequences were consecutively shot then analyzed. After five quality sequences were captured, the process was finished and the broiler was returned to the pin.

The best sequence to use for the chicken positioned two parallax points on all four views (Fig. 3.11). The chicken was in an upright stance with his neck at normal length. The legs were spaced apart and each view gave excellent detail.
Movement and sensitivity were detected in the pre-process phase of image processing. Movement and/or sensitivity issues appeared as distortion of the grayscale.
colors that represent the missing data. The sequence in Figure 3.12 showed good quality images of the chicken. Each image showed physical detail expected in viewing the live bird. Background noise and unwanted data were deleted by the selection of the interest area.

Figure 3.12  Grayscale images of Live Broiler
All four image views of the live bird sequence in the preprocess step

When the area of interest was determined, depth perception was the last analysis (Fig. 3.13). This sequence of images did not have any discontinuities that would affect 3D construction. The color scheme represented actual body posture as viewed in the original images. The color gradient changes from red to blue verifying actual depth was captured. The middle images of Figure 3.13 only have one leg showing in the final processing stage. The farthest leg was deleted in the selected interest area process due to the “push/pull” discontinuity tool not being able to interpret precise location in one of the images. Since there was a sufficient amount of data already shown for leg construction in the other images, omission of the leg did not yield model completion. The final model
Construction was completed in Geomagic (Fig. 3.14). As in all of the registrations, blind spots were accounted for in the live chicken and editing techniques were used.

Figure 3.13  Pseudo-color Images of Live Broiler

All four views of the selected area showing pseudo-color depth perception

Figure 3.14  Completed 3D Model of Live Broiler
System Limitations

The first limitation to building 3D models was capturing blind spots. Unseen regions by the camera end up as void spaces (Fig. 3.15). One solution to this limitation was to obtain another image, which was demonstrated for the horse and cow. In a large live model scenario, some image angles cannot be taken due to posture change. Small adjustments to original capture posture will misplace data unless stationary areas are taken in a second sequence. When an extra image is unavailable to acquire, the software’s editing tools create an exceptional depiction of the missing surface.

![Figure 3.15 Example of Void Spaces](image)

Both images show incomplete data caused by blind spots
a) Underneath side of pig
b) Top side of pig.

Editing in general was another limitation that existed. In areas where bridges are created to separate the holes of missing data, replaced mesh still cannot achieve true form. The top and bottom areas of some fiberglass models and cylinders were rounded and manipulated more accurately by the software, than the unseen spaces for the live chicken and larger models. These areas of concern resulted in a separate image taken for true form accuracy.
Another editing limitation was user skill. Some sections of combined images had an underlay that caused excess middle space to become part of the whole model which resulted in an inaccurate volume calculation. This was avoided before the wrap function was executed, closing the model completely. The seams were deleted of excess underlay if detected and the region was meshed together as one. This was completed by careful selection for deleting underlying data and bridging together the pieces. This problem was only experienced on larger model constructions. Knowing how much data was sufficient enough for deletion came by familiarization with the software. Other skill edits were the bridge connections for large holes. The large holes of incomplete data needed to be sectioned off for a correct fill. Some of these holes appeared at the junction of three images or places not seen by the camera. Bridges of different conformation were used in order for Single Fill to distinguish the different surfaces presented around a hole.

**Conclusion**

A 3D scanning methodology was created using a commercially available digitizer system to characterize surface area and envelope volume of poultry, livestock and equine. System accuracy (< 2%) was verified with the cylinder models. A separate recommendation for each species was developed in result of the fiberglass model analysis. The methods will have to be fine-tuned for live animals as observed in the live broiler test. The Creaform digitizer system successfully captured the three-dimensional shape of each animal in a rapid acquisition phase requiring minimal handling time and removal from its environment. The use of images prevented any destructive means of measurements to be performed.
REFERENCES


