# CATMAN - A PROGRAM TO MEASURE CAT-SCANS FOR PREDICTION OF BODY COMPONENTS IN LIVE ANIMALS

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## INTRODUCTION

A Whole-Body Computed Tomography System (CAT-Scanner) has been installed in the Department of Animal Science as a tool to measure body composition in live animals. The CAT-Scanner records a series of detailed, cross-sectional slices of the live animal which are transferred to a PC where CATMAN software is used to display the image and measure area and density of specific tissues or organs within each slice. The area estimates for tissue/component weights from each slice are then integrated to calculate volumes of the various tissues, which are then adjusted for their density to provide an estimate of the tissue weights in the body.

## CAT-SCANS

CAT Scanning makes use of the differential that exists between the rates at which the major tissues in the body attenuate X-rays. Attenuation measures are collected by an arc array of detectors which rotate 360° around the body in synchrony with the X-ray source. The data are then processed to resolve a matrix of CT values for the target body. CT numbers are a measure of density on a scale such that water is zero and air is -1024. As fat tissue is less dense than water it has CT numbers in the range of -10 to -200, depending upon the chemical composition and water content of the fat tissue. Muscle is more dense than water and has CT numbers in the range of 20 to 90. Very dense bone has CT numbers which approach 1000. The matrix of CT numbers is then displayed as an image on a monitor.

The biggest problem in using the CAT-Scanner as a tool for estimating body composition in live animals was the development of suitable procedures for quantitative use of the data. Most CAT-Scanners have standard software which is capable of recording simple measurements directly from the screen. These measurements include the linear distance between two points (eg fat depth, or muscle depth), areas (generally measured manually using a trackball), and the mean CT number within a region of interest. However the use of these rather simplistic measures of tissue depths and areas within the image to predict body composition is dependent upon the relationship between the particular measurement (eg muscle area, or fat depth) and carcass or body composition. From previous studies we knew that this relationship was not always high, particularly when there was a restricted range in carcass or live weight.

Another approach was to develop prediction equations based upon a histogram of CT numbers within the region of interest, as had been undertaken by workers in Norway. A problem with this approach was that the large number of variables derived from the histogram gave rise to complex prediction models with relatively large numbers of independent variables and so the final models were highly specific to the data set from they were derived. Altjough studies by the Norwegians validated the robustness of this approach for specific genotypes over a similar weight range, substantial bias occurred when equations were used to predict composition outside the original weight range.

This highlighted the need for continual validation of any prediction equations and the lack of flexibility in their application. This last point was particularly relevant for the UNE facility, as it was intended that the Scanner's major use would be the measurement of body composition in long-term growth studies. Therefore rather than relate the information contained in one, or small number of slices, to predict total body composition it was decided to use the Scanner to frequently sample the body and from these 2-dimensional images build up a 3-dimensional image of the components within the body. The concept was similar to a stereological technique first proposed by a 16th century Italian mathematician called Cavalieri, and still used to-day by anatomists in pathological research and diagnosis. Cavaleri showed that the volume of any object can be estimated from a series of parallel sections separated by a known distance and that the volume estimate from this procedure was completely independent on the orientation of the set of sections and the shape of the object. The advantage of such a procedure was that it provided a simple, quick and accurate procedure to predict the volume of body components within any irregularly shaped body, without the use of a prediction equation, which would continually need to be re validated. It has been estimated by a number of workers that even for a very irregular 3-dimensional structure like the human brain, a total of only 10 to 15 sections will provide an unbiased estimate of the 'true' volume with an error CV of less than 5%.

## CATMAN

Although a number of commercial software packages were available to undertake this analysis, they were either not capable of undertaking all the required operations in an efficient manner, or a large proportion of the cost was associated with pieces of hardware (eg frame grabbers) that were not required for the present analysis. Rather than utilise these commercial options which would have resulted in a cumbersome and often unsatisfactory end-product, a software package called CATMAN was developed in-house. The package was capable of displaying an image and then allowing the area of a specific tissue and organ to be to calculated and the results stored in an ASCII file. It was highly desirable that any software developed for the analysis of CAT-Scan images be capable of running on a standard PC system without the need for special cards, or frame grabbers, so that users could come to UNE to process animals or samples through the scanner and then take the scans away on disk to be processed at a later date on their own PC system. This would greatly reduce the load on the UNE resources and make the Scanner more attractive to potential users at other institutions.

The resulting software package for image handling was written in Microsoft Quickbasic with user interface routines from Quickwindows Advanced. Data from the UNE scanner must first be converted from the 16-bit CT format to an 8-bit binary image format in which the CT numbers are rescaled to a 256 grey scale. A similar conversion would be needed for other measure equipment, whether a CAT-Scanner or other such devices. The data conversion program has the option to adjust both the 'level' and 'width' of the CT numbers similar to the options on the CAT-Scanner. Therefore if the image contained information over the full range of CT values, the program could reduce a range of eight CT numbers to one value on the grey scale. However if the tissues of interest were only within the range of -256 to +256 CT numbers (such as fat and muscle) then it could be specified that only two CT numbers were combined to form one value on the grey scale.

CATMAN displays the scan on a VGA screen and allows the user to shade a pixel range within the image which correspond to various tissue types. That is, fat is shaded at the lower end of the range, muscle the middle, with the highest numbers corresponding to bone. The software can be used to shade preset ranges, or manually adjust the range to get the best differentiation between tissue structures on the screen. Once the user is satisfied that the shaded region depicts the tissue or organ within the image this area can be filled and the area, mean pixel value and variance calculated and saved to an ASCII file. This in effect automatically outlines the object(s) of interest. The image can then be instantly redrawn and other tissues highlighted for filling using a semi-automated procedure. There is provision to save information on up to 12 structures/tissues (or groups) from any one scan. There are also options which allow tissues to be 'dissected' on screen, ie a barrier may be drawn on the screen to separate subcutaneous fat from intermuscular fat and so allow the area of each to be calculated separately. Some components such as the rumen need to be excluded form most analyses and so there is the facility to save the 'dissection cut line' to a vector which may be recalled a number of times. There are also facilities to automatically outline components, fill anatomical objects of varying density and to measure distances. Since the program was written in-house it has been relatively easy to modify it to perform special tasks, such as saving bone outlines to a file as input to a CAD program. Figure 1 shows two scans from a Fallow stag pre- and post-rut. Subcutaneous fat is highlighted as the light grey region and demonstrates the large mobilization of subcutaneous fat over this period in deer.

In combination with the CAT-Scanner, the development of the CATMAN software has provided an efficient and accurate means for predicting muscle, bone and fat content in the body of live animals. The advantages of such a procedure is that it provides an unbiased estimate of body composition without the need for prediction equations. As discussed previously prediction equations are expensive to derive, and are generally very specific in their application. Some recent validation studies with sheep at UNE have confirmed that it is possible to achieve a high level of accuracy using CATMAN, with low error CV, compared with dissection procedures. For some components like mesentery fat which are difficult to separate from other low density material such as the digesta in the alimentary tract, the error is higher.

At least 10 to 15 scans are required to accurately predict the volume and subsequently the weight of any body component. However to accurately separate body fat into the carcass and non-carcass depots at least 10 to 15 scans are required of the abdominal cavity, generally making a total of 20 to 25 scans for the whole body. This increases both the cost and scanning time required to process an animal through the scanner. From loading a sheep into the cradle until the machine has finished processing the scans takes approximately half an hour. Add to this a further hour to transfer images from the CAT-scanner to a PC and to convert from 16 to 8-bit image files for use by CATMAN. Depending upon the number of components to be estimated and the skill of the operator it may take a further three hours to analyse the 25 images from one sheep. This gives approximately four to five hours to collect, process and analyse images from one animal, in addition to the direct cost of approximately $250 for use of the scanner. Although this may appear high it compares very favourably with the eight to ten hours required to slaughter and dissect or chemically analyse a carcass. Apart from the direct labour and operating costs the Scanner procedure has the advantage of being a non-destructive procedure and so the same animal may be processed a number of times during the course of an experiment. This overcomes many of the sampling assumptions which have to be made in the use of a serial slaughter procedure and provides the opportunity for more efficient statistical procedures, such as repeated measures analyses or including animal as a term in the model.

To date this procedure has been used in a number of major studies to estimate body composition at regular intervals in sheep, goats, deer, poultry and guinea pigs. Although it cannot scan live cattle the Scanner has been used to describe marbling patterns in cube rolls of beef. There is also the potential to use the Scanner to predict body composition in mice, using a large cartridge which would effectively allow a number of mice to be scanned at once. In addition to compositional applications there is also the facility to use CATMAN to measure shapes and areas from any digital array. Some unique applications that have been undertaken include identification of dingoes from digital photographs of paw prints.

## CONCLUSION

The CAT-Scanner in conjunction with CATMAN provides a new technique for Animal Scientists to accurately measure carcass composition in the live animal. This has the advantage of both reducing the total number of animals required in an experiment and also allowing repeated compositional measurements to be taken on the same animal. Disadvantages of the technique include the expense and the lack of portability of the machine, and for these reasons its use will largely be confined to research, rather than a commercial technique to measure body composition.

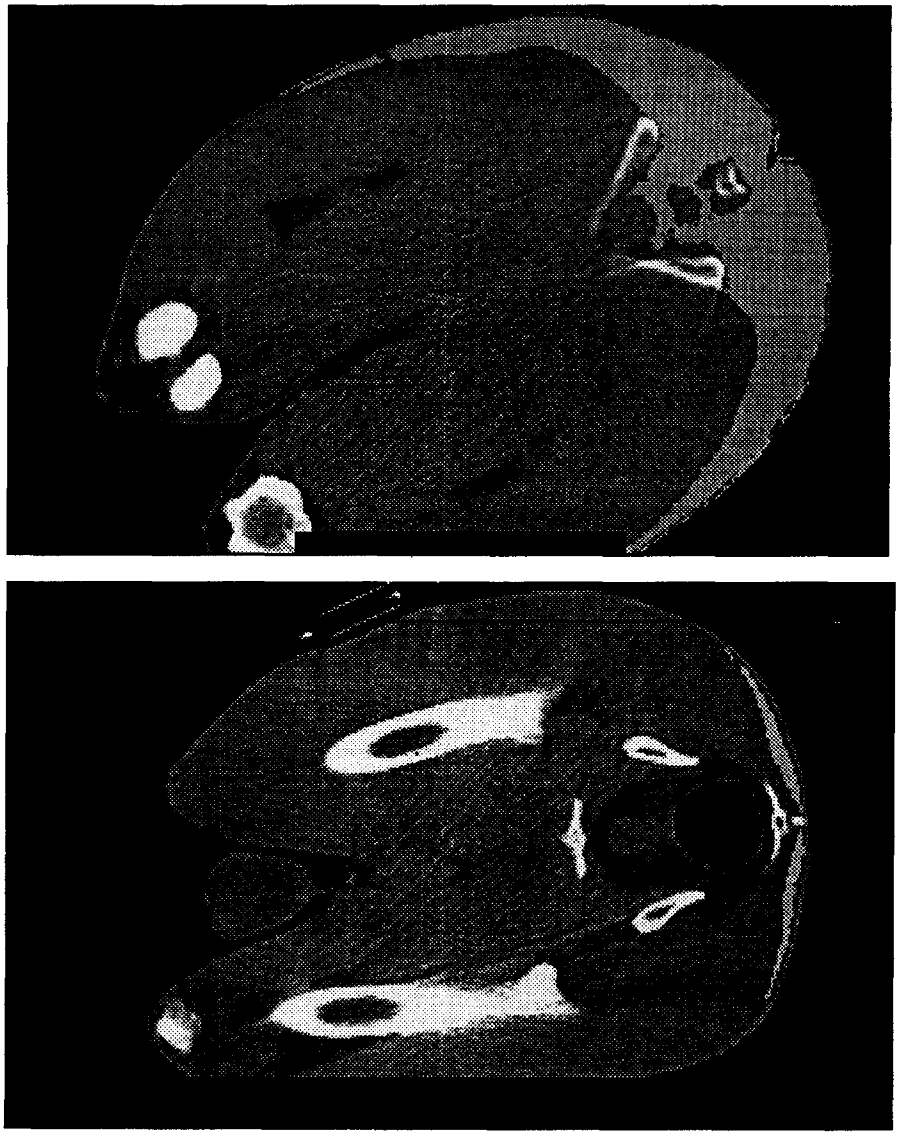

Figure 1. CAT-Scan images as displayed in CATMAN of the hindquarter of a Fallow stag taken before and after the rut. The subcutaneous fat depot has been highlighted and filled and the areas calculated in both images. Lean is shown as the darker grey and bone as the white region in the scans.