USOFT: An Ultrasound Image Analysis Software for Beef Quality Research

A.S. Leaflet R1437

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Summary

**Iowa State University has developed
technology for an objective evaluation of
beef quality by predicting the percentage of
intramuscular fat (IMFAT) in live animals
using ultrasound scans. For further
research, development, and evaluation of
this technology, a personal-computer based
image analysis software, named USOFT, has
been developed. USOFT is designed to
facilitate analysis of images collected from a
scan session. It provides a means of creating
a hierarchy of IDs to identify each batch,
image and file uniquely across many
scanning sessions, which is very useful for
research and data management purposes. It
also allows the user to identify overall image
quality and deficiencies, if any. USOFT uses
ISU's model for the IMFAT prediction and
also provides the output of texture
parameters for statistical analysis and new
model development. USOFT has served the
ISU ultrasound beef research team very well.
It has made data management, analysis and
reporting tasks easier and more flexible.
The evaluation of the current model for
IMFAT prediction has progressed faster with
the help of USOFT. It is being continually
updated for the needs of the research team
and for new model development.**

Introduction

Iowa State University has developed technology for
objective evaluation of beef quality by predicting the
percentage of intramuscular fat (IMFAT) from ultrasound
scans of live animals as well as carcasses. The
technology for live animal evaluation has been licensed to
a commercial company for field use (A.S. Leaflet R1326,
1996 Beef Research Report). For further research,
development, and evaluation of this technology, a
personal-computer based software has been developed,
which is copyrighted by the ISU Research Foundation,
Inc.

The software, USOFT, is an image analysis software
designed and developed specifically for processing
ultrasound images collected for beef quality grading
research. USOFT analyzes images acquired using a real-
time ultrasound scanner (Aloka 500V from Corometrics
Medical Systems, Inc., Wallingford, CT, USA) and a
frame grabber (Cortex1 or CTX100 from ImageNation
Corporation, Beaverton, OR, USA) following Iowa State
University's protocol of scanning live beef animals. The
primary use of USOFT is for prediction of the IMFAT
from a longitudinal image of *Longissimus dorsi* (ribeye)
muscle taken across the 11th, 12th, and 13th ribs. The
prediction models used in USOFT are also developed by
Iowa State University and are copyrighted by the ISU
Research Foundation, Inc.

USOFT Design

USOFT is designed to facilitate analysis of images
collected from a scan session. The software design
requirements were developed based on the experience of
ISU's beef quality research team. The following
paragraphs describe important aspects of the USOFT
design.

Batch Modes

USOFT allows several different modes to analyze
batches of images or different scanning sessions. There
are five batch modes implemented in USOFT's current
version 1.5: Browse mode, Preprocess-only mode,
Preprocess-&-Process mode, Process-only mode, and
File-Format-Conversion mode. The Browse mode allows
a user to sequentially view a selected set of images stored
in a single directory. It can be used to quickly identify
the overall quality of images, the "blank" images, or the
images with mismatched IDs and filenames. The
Preprocess-only mode allows preprocessing of a set of
images stored in a single directory. The preprocessing
prepares the images for later batch processing for IMFAT
prediction. A hierarchy of IDs is defined in this mode
allowing for the naming of each batch, image and file
uniquely across many scanning sessions. This mode also
allows for the identification of image quality and
deficiency and for the positioning of a rectangular box over
the region-of-interest in the image. Each image is stored
in a new file with the image header containing such
information as batch IDs, image quality code, and ROI
coordinates for later processing. This information is also
written in a text file for further statistical analysis.

The Preprocess-&-Process mode allows the most
flexibility for analyzing images for research use. It allows

for processing of the images in addition to all preprocessing functionality. For research studies, the same image can be processed multiple times with different ROI box positions. The Process-only mode allows automatic batch processing of a set of preprocessed images stored in a single directory. The batch ID, image ID, ROI position, and image quality code are read from the header in each image file. The File-Format-Conversion mode allows conversion among different file formats used for research.

Batch IDs

USOFT provides a means of creating a hierarchy of IDs to identify each batch, image and file uniquely across many scanning sessions. This is very useful for research and data management purposes. At the start of the Preprocess-only or Preprocess-&-Process modes, the user enters unique names for the batch ID, prefix and extension for new file names, and prefix for new image IDs. For example, appropriate names for the images collected at the Beef Nutrition Farm on January 6, 1995, for ISU research are: "ISU_Research" as Batch Class, "BN950106_E01" as Batch ID, "B" as Filename Prefix, "E01" as Filename Extension, and "BN950106_E01_" as Image ID Prefix. These names create the unique Image IDs and new file names for the specified animal tag numbers (provided that the original tag numbers were used to save the images).

Region of Interest (ROI) for Image Processing

A rectangular area or region of interest in the image is selected for texture processing to estimate the IMFAT. The placement of the box over the image to select the ROI is a very important step in preprocessing modes. The quality of the whole image as well as the ROI should be observed carefully. The criteria that should be strictly followed for the selection of the ROI and reliable prediction of IMFAT include: acceptable image quality, ROI free of any deficiency, ROI containing *Longissimus dorsi* muscle above and between two ribs, and even speckle or texture pattern in the ROI.

USOFT provides options of different box sizes to select the ROI. However, the current IMFAT prediction model is optimized for a 100x100 pixel ROI and processing is done only for that size of the ROI. The other sizes are allowed only for research trials. For images from young animals where the *Longissimus dorsi* muscle is too narrow for a 100x100 pixel ROI, prediction results should not be considered reliable.

Image Quality

The quality of an image is the first and most important element for reliable prediction results from image analysis. Therefore, the image quality should be a priority when scanning animals in the field as well as when determining the ROI box location for the IMFAT processing. USOFT allows the user to identify three levels of image quality: an overall quality, a primary deficiency, and a secondary deficiency. An overall subjective quality is assigned as Acceptable, Marginal, or

Reject. For Marginal or Reject quality images, a primary deficiency and optionally a secondary deficiency are identified that specify why the image quality is less than Acceptable. The user selection of the overall quality, primary deficiency, and secondary deficiency are written in the output files as image quality code for statistical analysis.

Overall Image Quality. A typical Acceptable quality image for the IMFAT prediction is shown in Figure 1. The features that identify an image with Acceptable quality include: clearly visible hide and subcutaneous fat layer(s) without any sign of uneven couplant or poor transducer contact; *Longissimus dorsi* muscle area taken from across the 11th, 12th, and 13th ribs with clearly visible rib shadows; even speckle or texture pattern in the muscle area; *Spinalis dorsi* muscle absent or nearly absent; and ROI box area completely free of deficiencies.
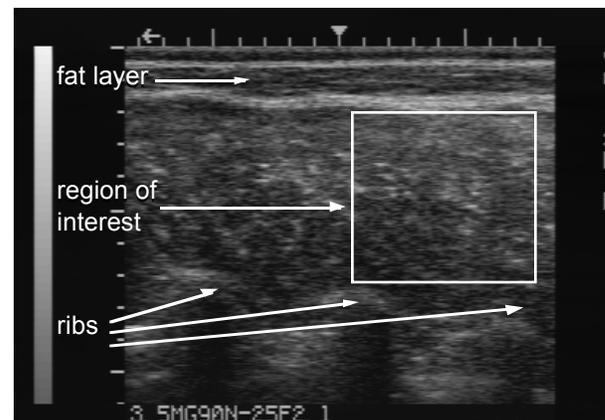
Figure 1: A typical longitudinal image of *Longissimus dorsi* muscle with an acceptable quality for IMFAT prediction.

Image Deficiencies. USOFT allows the user to identify commonly found deficiencies as primary or secondary reasons for Marginal or Reject quality. The Marginal quality is assigned if the deficiency does not significantly affect the ROI box area (where actual processing is done for the IMFAT prediction). The results from the Marginal quality should be used with caution and those from the Reject quality should be considered unreliable. The user can identify the following deficiencies, which are also shown in Figure 2.

1) Too much *Spinalis dorsi* muscle in the image (for incorrectly placed transducer).
2) *Longissimus dorsi* too narrow for the box (e.g., for young animals or incorrectly placed transducer).
3) Contact uneven between transducer and the hide.
4) Couplant uneven (not shown in the figure).
5) Couplant incomplete.
6) Blurred image.
7) No texture or speckle in the image (for a very low IMFAT or a very dark image).
8) No image (if a blank image was captured accidentally).

9) Other deficiency, e.g., electronic interference in the image.

The ROI box area should be free of any deficiency for reliable results of the IMFAT prediction. For example, an area that is unusually brighter than the *Longissimus dorsi* muscle, such as the *Spinalis dorsi* muscle or backfat, can have a higher IMFAT result. Likewise, an area unusually darker than the *Longissimus dorsi* muscle can have a lower IMFAT result than the *Longissimus dorsi* muscle itself. A darker area may be the result of poor transducer contact or uneven couplant.

Image Quality and IMFAT Prediction

Before applying the IMFAT prediction model to the ROI, USOFT attempts to check such aspects of the ROI quality as extreme cases of brightness, darkness, and texture patterns. If pre-defined criteria of the ROI quality are not met, the IMFAT prediction result is zero with a non-zero error code. In some cases, the processing may provide a non-zero error code with a predicted IMFAT result. However, any IMFAT result with a non-zero error code should be considered unreliable. The error codes and their possible meanings are listed in the USOFT User's Manual.

When an ROI is processed, USOFT writes an error code in the result file. An error of zero indicates that the processing of the ROI did not detect any problem. However, it is emphasized that USOFT is <u>not</u> designed for or capable of automatically evaluating the image quality and related deficiencies. The user should attempt to assess the quality of each image and use the results with caution for Marginal quality and ignore the results for Reject quality.

Using USOFT

USOFT disks provide an easy installation and configuration of the software on a PC. The system requirements are: PC (IBM-compatible) with 486 or higher processor; Microsoft Windows (version 3.1x or higher); and Super Video Graphics Array graphics mode (1,024 by 768 or higher resolution with at least 256 colors).

Once set up, USOFT starts with the main screen showing the File, Options, Window, and Help menus. The File menu includes Start New Batch, Stop Batch, and Exit items to allow batch processing. The Options menu allows the user to select the options for: displaying the toolbar for command buttons, automatically loading next image in preprocessing modes, default ROI size, default ROI position, and default overall image quality.

Batch Setup

On starting a new batch, a setup dialog box appears that walks the user through three steps. In the first step (Figure 3a), the user selects the batch mode, input file format and output file format. In the second step (Figure 3b), the user enters the batch IDs and finally, in the third step (Figure 3c), the user selects the input directory where

the images are stored and output directory where the new images and the result files are to be saved.

After the batch setup, USOFT displays a window showing the list of input and output files and the file counts. Another window displays an image along with image quality and ROI box size options, batch IDs, and command buttons. The command buttons are placed on the image window itself for speed and ease of use. These commands are Open Next File, Process ROI, and Save File. Figure 4 shows USOFT's main screen with the windows for the list of files and the image display.

Analyzing the Images

Once the batch is started, the user can analyze each image with the following simple steps. (1) Open the image file by clicking Open Next File command button. This reads and displays the next image in the window. (2) Position the box over the image for the ROI selection. If necessary for research, the default box size (100x100 pixels) can be changed using options provided on the image window. (3) Evaluate the image quality and select from options provided for overall quality and primary or secondary deficiencies, if necessary. (4) For Preprocess-&-Process mode, click Process command button to process the ROI for IMFAT prediction, which takes less than ten seconds on a Pentium class PC. (5) Click Save command button to save the image with the header information. (6) Repeat the first five steps for the next image.

For Process-only mode, no user-interaction is necessary once the batch is started. All the steps are done automatically for each file in the batch. For all the batch modes, appropriate result files are saved in the output directory. USOFT allows the user to stop the batch any time during processing; however, it is not recommended before the batch is complete to avoid additional data management tasks. When finished with a batch, the result files should be appropriately renamed and backed up for further analysis and reporting.

USOFT Image Files

USOFT works with the following four different formats of images for analysis. (1) Binary - Full size: The full size of the image has resolution of 486 rows by 512 columns of pixels and has the size of 248,832 bytes. (2) Binary - ISU size: The binary/ISU image has a resolution of 286 rows by 512 columns of pixels and has a size of 146,432 bytes. The image is truncated to discard approximately the bottom third in order to reduce the size of the file. This truncation discards only the portion of the image (below the ribs) that is not necessary for prediction of IMFAT. (3) L20 - ISU research format: This is an ISU-size binary image with header information. (4) L21 - ISU research format: The L21 file format is created by the USOFT preprocess batch modes. It is primarily a binary image format with text header information about such things as the Batch IDs, Image ID, size and location of the ROI, and image quality.

USOFT Result Files
USOFT provides up to three output files based on the batch mode.

Header file (*_header.*). The output of header information from L21 formatted image files is provided for further statistical or database analysis. The file is saved in text format with space-delimited columns for easy import in spreadsheet (e.g., MS Excel), SAS, or any other software. There are nine columns in the header file: batch class, batch ID, file name, image ID, ROI xsize, ROI ysize, ROI x1, ROI y1, and image quality code.

Percentage fat prediction file (*pfat.*). The IMFAT prediction results from Process batch modes are saved in a text file with space-delimited columns for easy import in spreadsheet (e.g., MS Excel), SAS, or any other software packages. There are three columns in the result file: image ID, predicted percentage fat, and error code.

ROI parameter file (pfatpc.*). For research use, USOFT provides the output of the texture parameters calculated from the ROI for analysis and new model development.

USOFT Performance and Upgrades
USOFT has served the ISU ultrasound beef research team very well. The evaluation of the current model for IMFAT prediction has progressed faster with the help of USOFT. It is being continually updated for the needs of the research team and for new model development. The future upgrades will incorporate the updated model for IMFAT prediction and will allow processing with different ROI box sizes. Additional functionality will also be added to make data management, analysis and reporting tasks more flexible and easier.

Implications

USOFT has proved to be a very useful research and demonstration tool for beef ultrasound research at ISU. USOFT has made it possible to analyze hundreds of images for IMFAT prediction in a few hours. Also, it has been instrumental in studying accuracy of the prediction model for such issues as multiple images per animal, multiple ROI box locations per image, and grading image quality for technicians or scan sessions.
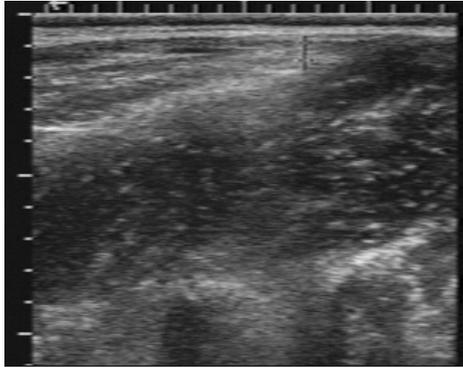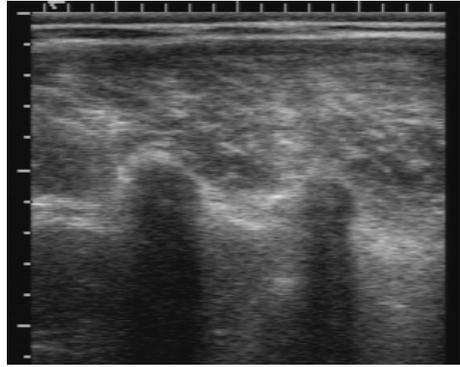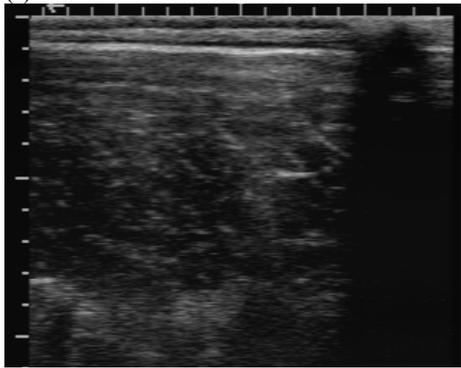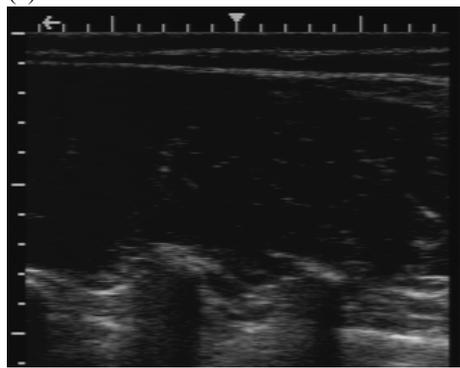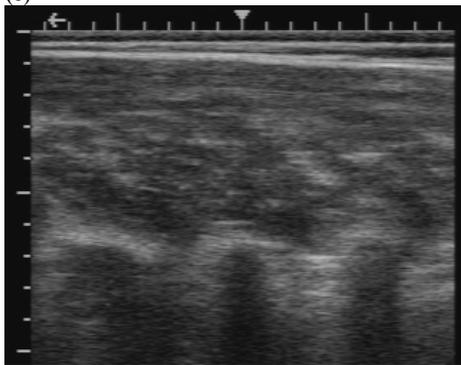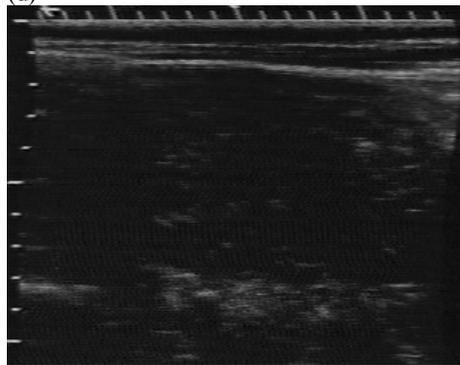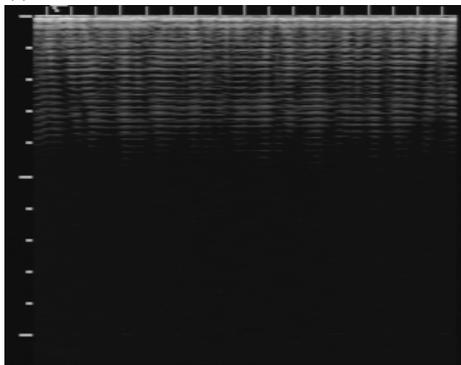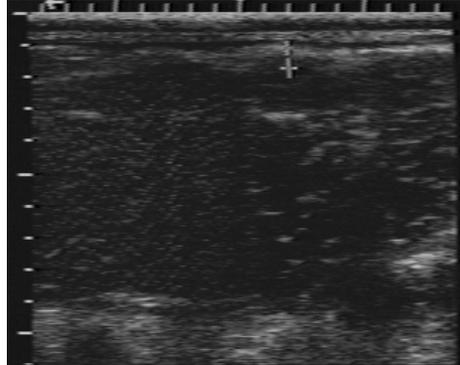
Figure 2. Image deficiencies: (a) Spinalis dorsi, (b) Narrow longissimus dorsi, (c) Contact uneven, (d) Couplant incomplete, (e) Blurred image, (f) No texture, (g) No image, and (h) other deficiency - interference.
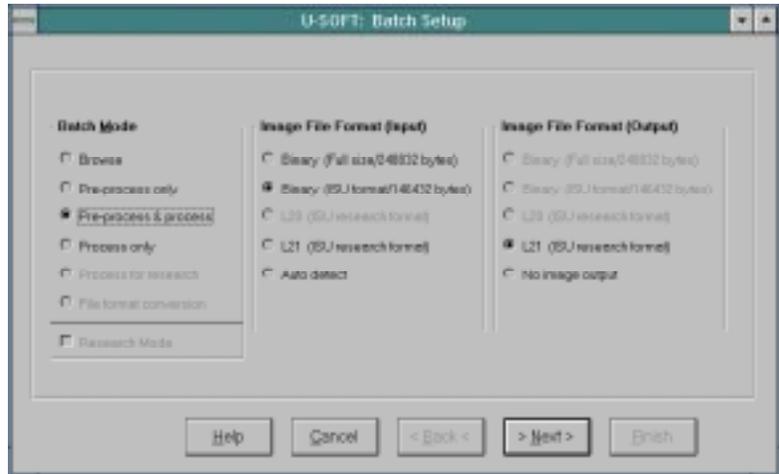
(a)
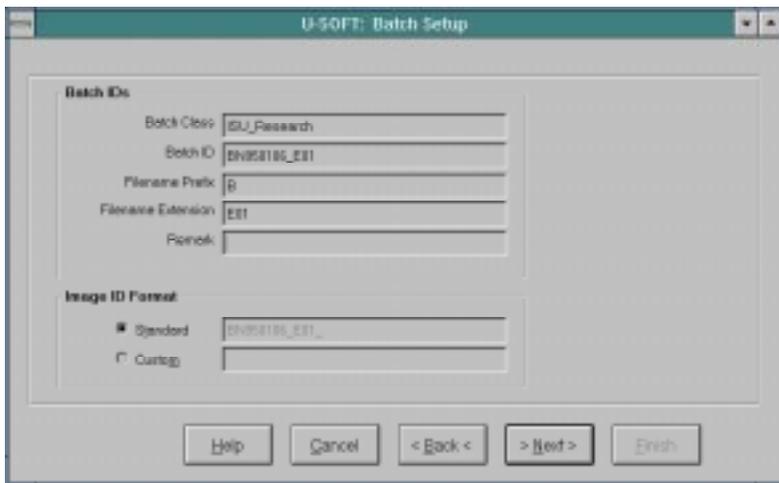
(b)
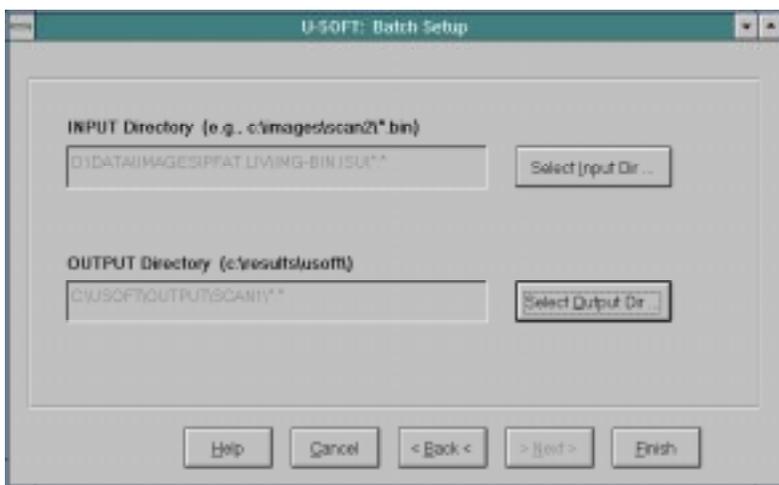
(c)

Figure 3. The steps of the batch setup process: (a) First step for options of the batch mode, input file format and output file format, (b) Second step for batch IDs, and (c) Third step for input and output directories.
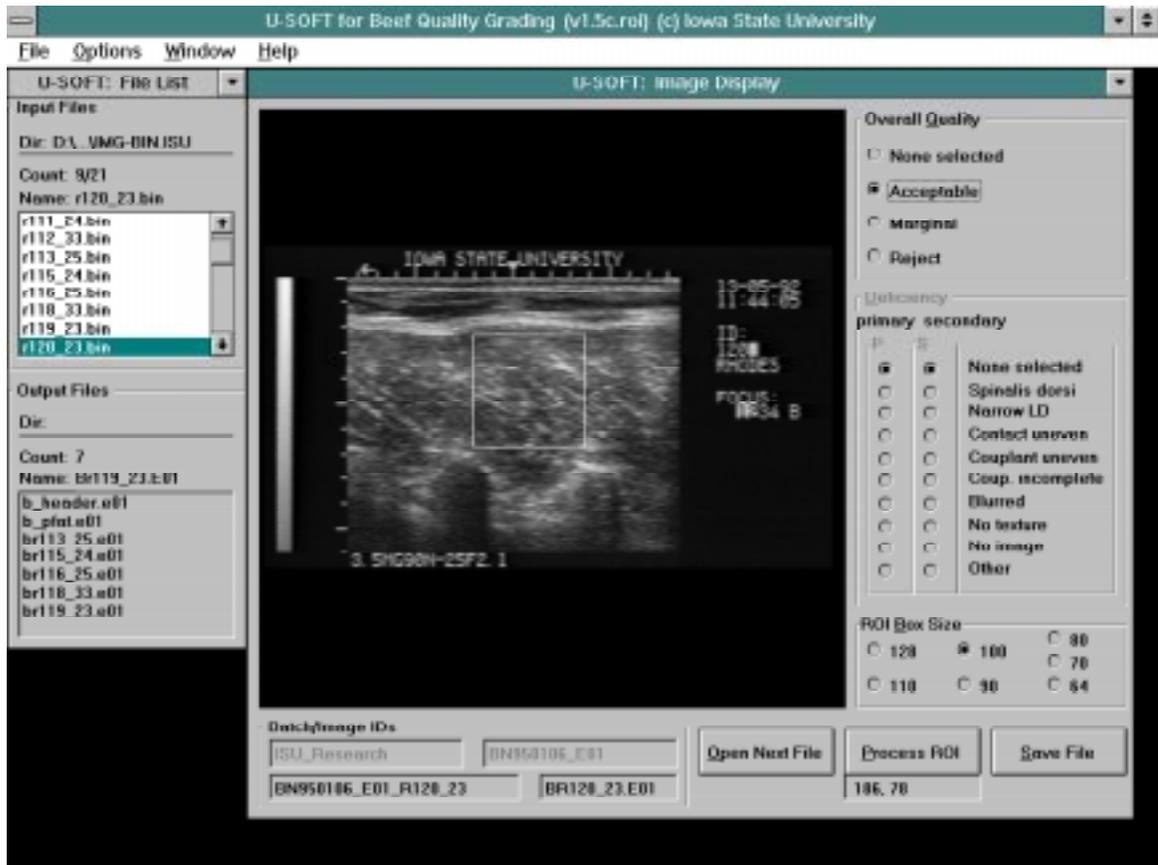
Figure 4. USOFT main screen with windows for analysis of a batch of images.