Utilizing image-based artificial intelligence for grading bovine oocytes

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A paper from the Proceedings of the
16th International Conference on Precision Agriculture
21-24 July 2024
Manhattan, Kansas, United States

Abstract.

For years, proper oocyte selection has been carried out with the precision of a lab technician's eyes. The classification of oocytes using image-based artificial intelligence is a new technology that IVF lab technicians, cattle genetics companies, and veterinarians can utilize. Via the aspiration of the follicles on a cow's ovaries, oocytes are able to be collected. Once oocytes are obtained from the ovaries of a cow, they are sent to an IVF lab to be cleaned and evaluated by a lab technician. Oocytes are graded under a microscope based on individual cell morphology. Following the protocol, established by the International Embryo Transfer Society (IETS), oocytes are classified on Grade 1 to 4 scale. We propose a machine-learning model (ML) approach for the oocyte grading process by training an ML model that can recognize oocytes based on their morphological appearance. Additionally, this model can classify oocytes with Grade 1 being the highest quality and Grade 4 being the lowest. Implementing this ML approach significantly reduces the time lab technicians spend grading and manipulating oocytes under a microscope. Rather than two to three minutes it takes for a trained human eye to classify oocytes by grade, the ML model can perform this task in a matter of seconds. Additionally, it reduces human error and bias during oocyte selection process. Not only can this new technology aid in the oocyte grading process, but it can also be used as a tool for lab technicians learning how to grade oocytes for the first time. The potential that high-caliber oocytes are being selected for fertilization, is likely to increase. In conclusion, the addition of ML technology has the capability to have a significant impact on the precision livestock industry.

Keywords.
Oocytes, Cattle, Imageomics, Artificial Intelligence

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Introduction

It is no secret that technology, such as machine learning (ML), is being integrated, in a variety of ways, into production agriculture. Technology based on artificial intelligence (AI) in agriculture commonly falls under precision agriculture. Many subjects within agriculture have already been exposed to this growing mechanization. However, one area of study that has yet to flourish like the rest, is the area of livestock. Precision livestock farming exploits tools such as artificial intelligence (AI) to enhance overall animal management practices (Berckmans, 2017). This research introduces ML to the livestock industry in a previously unexplored area - oocyte classification. The objectives for this research project include creating an ML model that can identify oocytes, in addition to training the AI model to classify and grade oocytes based on morphology.

Background

Today, oocyte collection and grading, following the ovum pick-up (OPU) process, is being performed by lab technicians in IVF labs. Oocytes are graded under a microscope based on their morphology by a trained eye. Experienced technicians look at specific morphology of oocytes such as the presence of cumulus cells, the appearance of the ooplasm, the structure of the zone pellicuda, and more. The International Embryo Transfer Society (IETS) is a global organization, that has developed a grading scale for the morphology and overall quality of oocytes. The grading scale this organization has developed categorizes the structures from Grade 1 to Grade 4. Once collected oocytes have been assigned an individual grade, they are stored for later fertilization. The selection of high-caliber oocytes for fertilization often leads to a greater chance that a top-quality embryo will develop, resulting in pregnancy (Erdem, Sevimli, & Aytaç, 2020).

Image-based AI is a tool that cattle genetics companies, lab technicians, and veterinarians can utilize. With the implementation of this technology, the time lab technicians spend manipulating oocytes during the grading process is greatly reduced. Instead of averaging two to three minutes for a trained human eye to classify the oocytes, this step can be performed in a matter of seconds with the help of image-based AI. Additionally, human error and bias are limited when it comes to oocyte selection with the help of AI. Not only can this technology aid in the oocyte grading process but it can also be used as a tool for lab technicians learning how to grade oocytes. Overall, the potential that high-caliber oocytes are being selected for fertilization, is likely to increase. The addition of this technology can have a significant impact on the precision livestock industry.

Pilot Study

To begin the initial steps of this research project, a pilot study was completed looking at different image-processing techniques that can be used to help in the completion of this project. Within this pilot study, Python coding through Google Colab was utilized to train an oocyte identification tool. The ten images used for the completion of this study came from the IETS Manual (Vol. 2, Appendix. 2). These images were pictures of individual oocytes, representing different oocyte grades (Grades 1 to 3), taken with the help of a microscope. The manual that contains these images is often used as a reference to teach new lab technicians how to grade oocytes based on the current IETS protocol. After the images from the IETS Manual were collected, each image was cropped to a unique pixel dimension of 367x367. With the help of Python code, unique filtering, and masking image-processing techniques were applied to each of the images. Thresholding techniques were additionally implemented, resulting in a new processed image of each oocyte. After visual and statistical analysis of the processed oocyte images, it was concluded that image enhancement techniques can determine the grade of oocytes. The ANOVA results indicated significant identification of oocyte grade (alpha = 0.10). With this, significant variability was imaged between the grades of oocytes. Grade 1 oocytes had the densest and largest number of pixels. With the completion of this pilot study, different image enhancement techniques can be noted and further executed with the development of this research project. After taking the time to carry out the different image processes used, study the resulting data, and consider influential limitations, it has been concluded that these methods could be of use with the completion of this research project.

Methodology

This research project which encompasses training image-based AI to classify bovine oocytes based on their morphological structure, will be furthered through the collection of additional images with the support of Simplot and their IVF lab. In collaboration with Simplot, oocyte images will be collected underneath a microscope by a camera, and an iPhone utilizing an attachment device connected to the microscope. Image collection of the structures by grade will take place after the oocytes have been graded by a lab technician's eye. To carry out this research project, a minimum of 500 images of oocytes would be collected, each with a unique pixel dimension of 1032 x 1096. The images of the oocytes will later be used to train a classification model. The ML model will be trained in parallel with the current IETS oocyte grading protocol (Grades 1 to 4). Individual images of oocytes will be captured from Grade 1 to Grade 4. Therefore, 125 individual oocyte images are to be collected per grade (Grades 1 to 4). In addition to collecting individual images of the oocyte structures, group images of the oocytes will be obtained for additional training of the ML model. A minimum of 100 images would be collected for groups of oocytes imaged together. Once the images are gathered, they will be pre-processed with the help of Python software to enhance image resolution or image color quality.

The camera and the iPhone will be used to collect oocyte images to train the ML models, so they can recognize images of different resolutions. To start, the ML model will be trained on single-structure oocyte images taken with the camera, due to their high quality and resolution. Later, the ML model will have the opportunity to develop the skill of classification of oocyte images through exposure to lower-resolution images. Images of groups of oocytes will be collected for further training of the ML model. The introduction of group images to the ML model will allow for the grading of oocytes in one image.

In addition to the collection of images, image, and oocyte data will be collected throughout this process. Information on each image will be accounted for within an Excel spreadsheet. This would include the specific image ID and pixel dimension. With this, the grade of each oocyte that is imaged will be determined by myself and 3 Simplot embryologists. The grade assigned by everyone for the given imaged oocyte will also be recorded in the spreadsheet. Additionally, the actual grade of the oocyte captured will be listed in the Excel sheet. Lastly, any information that can be obtained from the cow such as ID, age, breed, and more will be noted.

Once all images have been collected, each image will undergo pre-processing steps to enhance resolution and quality. This will be performed using Python software. Specific structures within the oocytes will manually be outlined and labeled after the image pre-processing steps. This task is completed to prepare for the training of the ML model using the image segmentation and classification approach in MATLAB software. The first model that will be utilized is the image segmentation model. This model investigates taking an oocyte image and pulling apart the areas of interest within the image. These areas of interest within the oocyte structure would include where cumulus cells are found, the structure of the zona pellicuda, and the ooplasm. The next model where the image will be entered is the classification model. This model not only looks at areas of interest that are important to the grade of the oocyte, but it also looks at the entire cell. Introducing these images to the segmentation and classification of ML models will train them to establish a grading system like the established IETS oocyte grading protocol.

Seventy percent of the image data will be used as training data and entered into the segmentation and classification ML models. With this, twenty percent of the oocyte image data will be fed into the models as testing data. Results from the training and testing data will be noted for an accurate assessment of the oocyte image data. The remaining ten percent of the image data that is collected, will be used for validation of the data set. Classification errors that appear can be due to malfunction of the models or image quality. With this, it can also be impacted by bias and variance within the data set. The validation step of this project should determine if the classification model needs tweaking due to the inability to recognize an oocyte. The results of these models from the oocyte image data entered will allow for the grading of oocytes through an image-based ML model.

Conclusion

With the completion of this research project, oocytes will be graded more efficiently and consistently using image-based AI rather than the human eye. This can already be shown by the findings from the pilot study that was performed. Image enhancement techniques in Python code can show oocyte morphology by grade. This was determined by significant ANOVA results and imaged visual variability of the oocytes by grade. With access to a larger image database, further oocyte classification through ML, and evaluation of findings this research project can be facilitated.

The next chapter of this research project will begin with Simplot's permission to grant oocyte image collection. This step will also allow for further classification of oocytes by grade. The training of an ML model to identify oocytes by grade will improve bias and time spent manipulating the cells. Obtaining images with appropriate resolution and pixel dimension is important to the success of the ML model and its ability to classify oocytes. In addition, the ML model has the opportunity to be more accurate with a larger oocyte image dataset. Once the ML model is trained on individual and group images of the oocytes by grade, the model will be tested and validated for its efficiency. With the help of a trained ML model, high-quality oocytes will be utilized, leading to better reproductive outcomes. Overall, the technology created in this project will have a positive impact on the sustainability of livestock operations.

Acknowledgments

I would like to give a special thanks to Dr. Benjamin Wenner and Dr. Alvaro Garcia Guerra for their guidance and support throughout this project. I'm also grateful to The Ohio State University for providing the necessary resources to help in the beginning steps of this project. I also wish to acknowledge my colleagues at The Ohio State University for their insightful feedback during this process. Additionally, I would like to express my deepest gratitude towards Simplot for their collaboration and interest in allowing this research project to be conducted.

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