final report

Project code: B.NBP.0752

Prepared by: Bram Van Dun, PhD, MEng
Independent consultant

Date published: January 2013

PUBLISHED BY
Meat & Livestock Australia Limited
Locked Bag 991
NORTH SYDNEY NSW 2059

Independent Technical Review of ePreg

Meat & Livestock Australia acknowledges the matching funds provided by the Australian Government to support the research and development detailed in this publication.

Abstract

This independent review evaluates the ePreg system, a hand-held, non-invasive portable producer operated cattle pregnancy detector (ePreg). It provides recommendations on the likelihood the ePreg reaching a “yes/no” pregnancy accuracy of 95% (sensitivity) and 97% (specificity). It reviews the currently available ECG literature and commercial applications. It proposes modified and new development approaches to increase the likelihood of the required pregnancy accuracy, including indicative costs, timelines, and likelihood of success. Based on all available information, it is judged to be possible to achieve an accuracy of 90% with the current setup of the ePreg. However it is evaluated to be next to impossible to achieve the targeted 95 and 97% accuracies above, unless some radical changes are made, which will not guarantee success because of extreme challenges to meet the targeted accuracy given the difficult measurement conditions in the field.

Executive summary

This independent review evaluates the ePreg system, a hand-held, non-invasive portable producer operated cattle pregnancy detector (ePreg). It provides recommendations on the likelihood the ePreg reaching a “yes/no” pregnancy accuracy of 95% (sensitivity) and 97% (specificity).

First, the electrocardiography (ECG) literature is reviewed. It is shown that maternal ECG is easily detected, and that standardised ECG databases are available which can be used for training classifiers, or to evaluate the effect of different signal-to-noise ratios (SNRs). Foetal ECG detection is a different matter however. Different detection techniques have been proposed in the literature, with varying degrees of success. In humans, accuracies (success rates) have been achieved up to 90%, with a significant variation in accuracy depending on gestational stage. In all studies the mother’s abdomen is covered with an as wide an area as possible. The most promising technique is the one from Martens et al. (2007), who proposed a promising multichannel technique called sequential analysis (SA) which has been evaluated successfully in real-world environments. It incorporates a priori known information about foetal ECG (fECG) morphology, and detects the fECG by estimating and removing the interference signals (including maternal mECG) step-by-step, using a priori information about the interference signals and the signal of interest. It achieves detection sensitivities up to 100%, with a significant drop between 28-32 weeks of gestation. The algorithm is robust against noise, with still a good detection reliability at -15 dB SNR. In cows it is more difficult and studies are more scarce. Again, the trend is found that detection sensitivity depends on gestational stage, but now with a monotonic decrease of sensitivity with decreasing gestational age. Electrodes should be positioned as spatially separated as possible to better cover and record the fECG. Signal processing techniques are proposed that can separate mECG from fECG in cows. Unfortunately, the size of the cohorts for evaluation is generally small in all these studies.

Commercially devices are only available for humans. They are able to trace fECG and monitor their heart rates. It might be interesting to reverse-engineer some of these devices.

The phonocardiography (PCG) literature has not been reviewed because of the limited knowledge of the author about the topic.

After the literature review, the current accuracy of the ePreg is reported, which varies between 70 and 90%, based on communications with HEARD Systems. The variability is yet to be explained. This will provide a reference for future modifications.

A short translation of techniques available in the field of electroencephalography (EEG) towards ECG is provided. Techniques that could improve the SNR of the fECG by combining multiple channels are discussed, and the importance of optimal electrode positioning are highlighted.

Then, nine possible weaknesses and their suggested improvements are listed. Two main suggestions for suboptimal detection performance have been identified. First, because of the practical design of the electrode head and its reduced coverage of the abdomen, it is likely that in some occasions the ePreg recording channels just do not record the fECG because of an

unfavourable position of the cow's foetus. By improving the covered area (more separated electrode positioning), this issue might be addressed. Second, it is very likely that excessive noise is responsible for poor detection. It is of paramount importance to identify the sources most responsible for poor detection, and remove them accordingly. Obtaining data that is as clean as possible should be the first priority before even training or using the detector.

Apart from these two suggested improvements, seven other ones are identified. First, it might be worthwhile to look into other types of detectors using matched filters or correlograms because the current classifier might be too sensitive for background noise and trigger to the wrong structures in the data. Second, feedback to the user with information about the impedance between the electrodes can indicate that a repositioning is in order to prevent a poor recording. Third, because different gestational stages have different detection sensitivities, it might be interesting to report on the sensitivity for specific foetus's age categories to inform the end user about its possibilities. Fourth, as multichannel ECG data is recorded, a proper multichannel processing will likely improve detection. Fifth, because the current classifier for detection seems to be sensitive to noise, a training set needs to be developed which is clean and without many artefacts to allow proper training. Sixth, to improve the confidence of the operator about the presence of the fECG, a specific value indicating the likelihood of a foetal ECG detection could be passed on visually. Finally, similarly as above, an experienced user could be provided with acoustic PCG and visual ECG feedback to improve detection in the events the detector fails. Costs, timelines, likelihoods of success and impact on modifications of the ePreg device are provided.

Based on all available information, it is judged to be possible to achieve an accuracy of 90% with the current setup of the ePreg. For a specific data set obtained with the ePreg (the Beta data set), and with proper noise rejection, this accuracy has been obtained already. However, performance still seems to be variable, so it needs to be identified why different data sets result in such different accuracies.

However it is evaluated to be next to impossible to achieve the targeted 95 and 97% accuracies, unless some radical changes are made. Better coverage of the foetal ECG and improved data quality with much less noise are a requirement. As the literature suggests that there is a lot of variability in detection, mainly dependent on the age of the foetus, sensitivities need to be separated for different gestational stages. In addition, significant additional fundamental research needs to be carried out on foetal ECG detectors. Even with all these modifications successfully implemented, no success is guaranteed because of extreme challenges to meet the targeted accuracy given the difficult measurement conditions in the field.