Using Rule Induction to Analyze Intrauterine Pressure and Oxytocin Data for Surgical Interventions in Labour

M.J. Stockton¹, E. Grant², T.C. Henderson³

¹Department of Marketing and Communications, Longwood University

²Joint BME Department, UNC-Chapel Hill & North Carolina State University

³School of Computing, University of Utah

egrant@ncsu.edu

INTRODUCTION

Uterine activity analysis is of major importance in the management of labour in childbirth. It has been shown that insufficient or excessive activity can delay progress and lead to many serious problems for both the mother in labour and the foetus, e.g., the decision to perform a Caesarean section [1]. Quite often, oxytocin, a drug that stimulates contractions, is used [2]. The aim of this project was to investigate the effectiveness of using an artificial intelligence technique known as rule induction in the control of oxytocin administration [3]. A doctor or midwife controls the rate of administration of oxytocin, by intuitively increasing or decreasing the infusion rate. The number of contractions the patient has and the strength of these contractions are monitored by examining the patient, or feeling the stomach, and decisions are based on this. Occasional checks of cervical dilation are noted as an indication of how far labour has progressed. So, a goal of the reported research is the provision of a computer-assisted system to advise medical practitioners whether to increase or decrease the infusion rate. Or, to have a credible guide that explains why a classification was made, including a percentage of certainty. Commonly, sensor data is gathered in the domain by using a tacodynamometer, or by measuring the intrauterine pressure in the amniotic behind the foetal head. However, fluid the tacodynamometer data is very noisy due to relative motion between the sensor, the mother, and the tissue. Alternatively, intrauterine pressure measurements require the pressure sensor to be placed internally, which involves the puncturing of the foetal membrane, an action that can itself stimulate contractions. And, one labour can differ greatly from another. Numerous approaches have been proposed for deriving objective evaluations of intrauterine pressure, from recorded waveforms gathered over time, including Steer et al. [4]. Steer et al. proposed an *activity unit*, a product of peak pressure and duration of contraction. When the *activity unit* is summed over time, i.e., frequency, the activity unit approximates to a measure of area.

Rule Induction is important in the field of machine learning. Rule based inductive learning is a technique that derives classification rules from a training set of examples that are the input to the system. The training set consists of a set of attributes and the desired outputs, known as classes. The attributes, paired with the particular class, represent the output expected by an ideal system. The system should give expected outputs on newly presented inputs if a good, comprehensive training set was used. During the learning process the rules are continuously modified under strictly defined conditions to reduce the outputs between the actual outputs produced by the rules and the desired output.

Clark and Niblett developed CN2 [5] in 1986. CN2 was designed with the aim of inducing short, simple comprehensible rules in domains where problems of poor description language and/or noise may be present. The induced rules are in a form similar to production rules. An important feature of the search for such rules is the relaxing of the requirement of complete consistency of rules within the training data during their generation, in order to minimize the problems of noise in the description language. This has the benefit of allowing induction to be halted in regions of the search space where where is little training data to guide the system, where further search is as often damaging as beneficial, similar to pruning of trees, as is done by NewID.

NewID is an ancestor of Quinlan's ID3 (Iterative Ditchotomiser) [6] and the algorithm is very similar. It expresses its induced knowledge in terms of a decision tree. A decision tree is a conventional tree with nodes and arcs. Internal nodes (or decision nodes) are named with the attributes and the arcs are labelled with the possible values of the attributes. Each leaf node specifies a decision. Any object is associated with a unique leaf of the tree. This association is accomplished by a procedure that begins at the root node and traces a path to a leaf by following the arcs that correspond to the attribute values of the object being classified.

MATERIALS AND METHODS

The data used in this project came from Phillips [7], see Fig.1 and 2. Cartiographs from four patients were digitized. The digitized data was used to develop a program to extract the features of intrauterine pressure, that subsequently became the attributes for classifying the signals. Care was taken to mark the points where labour progresses adequately or inadequately. Data related to oxytocin infusion rates was recorded simultaneously with intrauterine pressure. This action provided accurate classification verification, because the rate of infusion at any point during labour indicates a medical practitioner's decision on contractile activity.



Fig.2. Second Stage Intrauterine Pressure

Fig.1 represents the first stage of intrauterine pressure measure, it shows peak contraction, duration and frequency. Fig.2 shows a high frequency component superimposed onto the contrction peaks, this is the effect of *bearing down*. The resulting pressure is beyond the range of the recorder.

The extraction software developed to calculate values from input data was tested at procedure and system level and was shown to calculate the features satisfactorily. But, the software may tend to overestimate the activity where there are increases in pressure due to patient movement and other noise. An end of contraction is noted if the pressure drops within a threshold of the baseline pressure value, therefore the area may be overestimated when there is a long period of pressure just above the threshold that is not a contraction. One possible solution to this problem may be to incorporate a procedure to measure the gradient of the line and if the gradient becomes low enough, i.e., it "levels out" enough, then the contraction can be seen as ended.

RESULTS

The extracted features from intrauterine pressure signals, used as attributes in the learning process were: (1) peak pressure of every contraction, (2) the number of peaks per contraction, (3) duration of every contraction, and (4) the area under the intrauterine pressure curve calulated over the duration of each contraction. Intrauterine pressures from two labours were used to generate the attribute and example file. Part of an attribute, example, classification file is shown in Table 1. Table 2 shows rule trees generated for data set one, starting with the current contraction only. Rule trees are then generated using attributes from the current contraction plus current contraction – n (n =1, 2, etc.).

Peak Pressure	Number of Peaks	Duration of Contraction	Area Under Curve	Classification		
73.15	3	85.00	2876.6	с		
135.85	1	70.00	4220.25	а		
66.55	1	80.00	2941.25	a		

Format of	Total	Internal	Leaf Nodes			
Attributes	Number of	Nodes				
	Nodes					
Current Only	47	23	24			
Current & 1	37	18	19			
Previous						
Current & 2	35	17	18			
Previous						
Current & 3	35	17	18			
Previous						
Current & 4	33	16	17			
Previous						
Table 2						

CONCLUSION AND DISCUSSION

With the assistance of Dr. Fiona Fairlie [8] a set of attributes was identified in data files of intrauterine pressure and oxytocin simultaneously recorded during labour. An attribute extraction program to automatically extract these features was then produced. Experiments were conducted using the rule induction algorithms NewID and CN2. From these experiments NewID, with its tree pruned with a 4% threshold, produced an acceptable set of rules. This tree classified the oxytocin level, given new data, at an average overall accuracy level of 73.8%. In addition the rule tree generated had a comparatively low complexity level of 58 nodes. The results from automatically induced rules showed a higher correspondence to 'actual' values than those derived using Steer's [4] method for controlling oxytocin levels. It was concluded that Steer's approach is too rigid for this kind of domain. Learning from examples may hold the answer for an optimal system for controlling oxytocin level, decreasing cesarean sections, and shortening labour. The main problem encountered in all induced rules was that of predicting a decrease in oxytocin. NewID's unpruned, highly complex tree could achieve the best average accuracy level of 41.9%, hence two or three decreases in oxytocin will be wrongly predicted in a single labour.

REFERENCES

[1] Shu-Qin Wei, Zhong-Cheng Luo, Hui-Ping Qi, Hairong Xu, Fraser, W.D., "High-dose vs low-dose oxytocin for labour augmentation: a systematic review," In: American Journal of Obstetrics & Gynecology, October 2010, pp 296-304.

[2] Guideleines for the use of Oxytocin in Labour, Report: University College London Hospitals, June 2010, 7 pages.

[3] Creaney, M.J. (1991) "The use of rule induction in the analysis of intrauterine pressure signals." MSc, University of Strathclyde.

[4] Steer, P.J. et al (1975) "Uterine activity in induced labour." Br J. Obstet. Gynaecol. vol 82, pp 433-441.

[5] Clark, P. and Boswell, R. (1991) "Rule induction with CN2: some recent improvements." EWSL-91.

[6] Meta-Learning in Decision Tree Induction, Author: Krzysztof Grabczewski, Pub: Springer, ISBN: 978-3-319-00959-5, 2014.

[7] Philips, G.F. (1986) "The contractile activity of the human uterus during labour." PhD, University of Strathclyde.

[8] Fairlie et al (1988) "An analysis of uterine activity in spontaneous labour using a microcomputer." Br. J. Obstet. Gynecol. Vol 95, pp 57-64.