Application of the Exponential Weighted Moving Average in Detecting Morbidity of Newly Received Calves in a Commercial Feedlot

STAT575 Writing Project

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Abstract

The objective of this project is to use feeding behavior of newly received calves in a commercial feedlot to detect morbidity and determine whether EWMA procedures are comparable to the traditional method based on pen riders. The experiment was conducted for 107 calves in a commercial feedlot near Yuma, Arizona. The Growsafe System® was used to monitor the feeding behavior of all experimental animals. The exponential weighted moving average (EWMA) SPC procedure was run to predict morbidity. The results of the EWMA procedure and the pen riders were compared to each other. EWMA could detect morbidity 3.49 days on average earlier than pen riders with an overall 80.37% accuracy, suggesting that the method of analyzing feeding behavior of newly received calves by statistical process control may be a viable alternative to the traditional one.

Introduction

Motivation and Objective. Morbidity in newly received calves in commercial feedlots is a major problem for the cattle feeding industry. In general, medical treatment is more effective the earlier signs of morbidity can be detected. The current method to detect morbidity is dependent on the visual recognition of experienced feedlot pen riders. However, a study by Wittum et al. reported that 68% of the calves with lung lesions at slaughter were never detected morbid by pen riders, suggesting that the current method may not be satisfactorily effective. More effective methods are desired for detecting morbidity of calves as early as possible. The feeding behavior of an animal is an important aspect because morbid animals usually lose their appetites. Therefore monitoring the feeding behavior for each animal may be helpful in detecting morbidity. A radio frequency (RF) system, called Growsafe System®, can help monitoring the feed behavior of calves. The objective of this project is to use the exponential weighted moving average (EWMA) procedure to analyze data from the system and decide whether this method is more effective than the visual recognition of pen riders in detecting morbidity.

Description of the Experiment

A 29-day experiment was run at a commercial feedlot near Yuma, Arizona. All experimental calves were placed in a feedlot pen where the Growsafe System® was installed. Each calf was assigned an Allflex® ear tag (Allflex USA, Dallas USA, Dallas Ft. Worth, Airport, TX 76193) with an individual identification number and an Allflex®

RF ear tag with an individual RF identification number. Growsafe® System helped monitor the feeding behavior of each experimental calf. Every 5.25 seconds the RF system recorded whether or not a calf was present at the feeding bunk. For each calf, the data was recorded as 1 (present) or 0 (absent). Normal feeding procedures and other treatments of calves in commercial feedlots were applied to all experimental animals. Pen riders with 8 to 15 years of experience took the responsibility of detecting morbid animals by visual recognition. Nasal discharge, coughing, depression and loss of appetence are usual signs that the pen riders use for detecting morbidity. Calves that were identified as morbid by pen riders were immediately pulled from the pen and were given medical treatments. The date each morbid calf was pulled for the first time was recorded and it was considered as the day on which the individual animal was identified as morbid by pen riders. The calves that hadn't been identified as morbid by pen riders were considered healthy.

Description of Methods

Description of Statistical Process Control. Statistical process control (SPC) is an application of statistical methods to monitor and adjust processes. A process is considered to be in statistical control (or statistical stability) if the variation is attributed only to chance causes. When the variation is attributed to assignable causes, the process is considered to be out of statistical control (or statistical instability).

Control Charts are tools that provide us with the information of in-control or out-of-control status of a process. A control chart contains a centerline, which represents the target or average level of the process. It also contains two lines called upper control limit (UCL) and lower control limit (LCL). The control limits are chosen such that most points are in the control limits if the process is in statistical control. When a point falls out of the control limits, the process is considered to be out of control.

The general model for a control chart is

$$UCL = \mu_0 + L\sigma \qquad (1)$$

$$CL = \mu_0 \qquad (2)$$

$$LCL = \mu_0 - L\sigma \qquad (3)$$

where μ_0 is the target or desired mean of the process, L is the width of the control limits and σ is the standard deviation of the process when in control.

The choice of control limits is associated with type I and type II errors. A type I error indicates that the process is out of control when no assignable cause is present, and the probability of a type I error is denoted by α. A type II error indicates that the process is in control when it is actually out of control, and the probability a type II error is denoted by β. Small values of both α and β indicate satisfactory accuracy and reliability of SPC procedures. However, when the control limits are widened, β increases while α decreases. Therefore, a balance between α and β is always required in SPC procedures.

Description of the EWMA Control Chart. The exponential weighted moving average (EWMA) represents a method for detecting small shifts in the process mean. It is typically used with sample size of $n = 1$ at each time period.

The exponentially weighted moving average is defined as

$$a_i = \lambda x_i + (1-\lambda)a_{i-1}$$

where a_i is a weighted average of all past and current sample values, where $a_0 = \mu_0$. That is, the staring EWMA value is the target value. The parameter λ is a weighting constant such that $0 < \lambda \le 1$. The value of x_i is the ith observation in the sequence. According to the definition, EWMA is a sequential analysis because it uses the information of past observations as well as the present to decide whether the process is in control. Therefore, it is insensitive to normality assumptions and is suitable to be used for single observations per sampling time. It is also useful for analyzing correlated data.

By substituting recursively, we get the following equation

$$a_i = \lambda \sum_{j=0}^{i-1} (1-\lambda)^j x_{i-j} + (1-\lambda)^i a_0. \tag{4}$$

The weights $\lambda(1-\lambda)^j$ decrease geometrically from the present back to the past. The largest weight is assigned to the current sample observation, which means the decision depends most on the current observation. By choosing λ appropriately, we can tailor EWMA charts for time sensitivity.

The EWMA control chart is defined as

$$UCL = \mu_0 + L\sigma\sqrt{\frac{\lambda}{2-\lambda}[1-(1-\lambda)^{2i}]} \tag{5}$$

$$CL = \mu_0 \tag{6}$$

$$LCL = \mu_0 - L\sigma\sqrt{\frac{\lambda}{2-\lambda}[1-(1-\lambda)^{2i}]} \tag{7}$$

where L is the width of the control limits, which is a parameter for EWMA control charts. During analysis, when a point falls out of the control limits, the process is considered to be out-of-control.

The parameters L and λ should be chosen to achieve the desired average run length (ARL). ARL is the average number of time periods taken before an out-of-control condition is signaled. Therefore, when the process is in control, the ARL should be as long as possible; when the process is out of control, it should be as short as possible. Based on past studies, the values of λ such that $0.05 \le \lambda \le 0.25$ work well in practice. To detect smaller shifts, it is better to use smaller values of λ, and vice versa. $L = 3$ (the usual 3-sigma limits) works reasonably well, particularly with large value of λ.

Statistical Analysis Using EWMA procedures

Data Management. Each day was divided into eight 3-hour time periods. The raw data obtained by the Growsafe® System was converted into the number of counts per 3-hour period. The first two periods, i.e., 0:00-3:00am and 3:00-6:00am were removed from the data set because there is no food in the bunk at that time. The first day was not used because animals need to become acclimated to the new environment. Each calf was an experimental unit, and each 3-hour period for each calf was one observation.

EWMA procedure. The target was determined by previous studies for healthy calves. The feeding time of 120 in a 3-hour period was used as the target mean. For this project, fast response to shifts in the mean was desired; consequently a large λ value was chosen. The values $\lambda = 0.25$ and $L = 3$ were selected for the EWMA chart.

An EWMA chart was conducted for each animal using SAS. The first point that fell out of the lower control limit after the second day was a signal that the calf was sick during that time period. Each animal was classified as morbid or healthy. If an animal was classified as morbid, the date that the process was out of control was also recorded.

Analysis of results by the EWMA procedure. The results using EWMA and decisions by pen riders were compared and for those that both the EWMA and the pen riders classified as morbid, a paired t-test was conducted to determine whether EWMA could detect morbidity earlier than the pen riders.

The reliability of the EWMA procedure was obtained by estimating α, β and the overall accuracy J. The data for this project can be generally presented as in table 1.

		EWMA		
		Morbid +	Healthy -	Total
Pen Rider	Morbid +	a	b	n_1
	Healthy -	c	d	n_2

Table 1: The general table for comparing results of EWMA and the pen riders.

α was estimated by $\hat{\alpha} = c / n_2$, β was estimated by $\hat{\beta} = b / n_1$ and J was estimated by $\hat{J} = (a + d)/(n_1 + n_2)$.

Results and Discussions

Results. Table 2 shows the results of the EWMA procedure and the pen riders. Individual EWMA control charts are tabulated in appendix A. Pen riders identified 53 out of 107 as morbid while EWMA identified 66 as morbid. The pen riders and the EWMA procedure agreed on the morbid or healthy status for 86 calves and disagreed on the other 21 calves.

EWMA				
		Morbid +	Healthy -	Total
Pen Rider	Morbid +	49	4	53
	Healthy -	17	37	54
	Total	66	41	107

Table 2: The results of the EWMA procedure compared to that of the pen riders.

Table 3 shows estimates of β, α and J using the values $\lambda = 0.25$ and $L = 3$. β (0.0755) is extremely small, indicating that EWMA is very sensitive to shifts in the process. However, α (0.3148) is relatively large, which means we have classified more healthy calves as morbid than we would like. The overall accuracy is 0.8037.

$\hat{\beta}$	$\hat{\alpha}$	$\hat{J}$	$1-\hat{\beta}$	$1-\hat{\alpha}$
0.0755	0.3148	0.8037	0.9245	0.6852

Table 3: Estimates of β, α and J.

For calves that were classified as morbid by both the pen riders and the EWMA procedure, a paired t-test was run. The EWMA procedure detected morbid calves 3.49 days earlier on average than pen riders with a p-value of 0.001, which means the EWMA procedure could detect sickness significantly earlier than pen riders.

Conclusions. The results of this project suggest that monitoring of feeding behavior of feedlot calves and analyzing the feeding data on line by the EWMA may be a good alternative method to detect morbid animals. By detecting morbidity early, this method may help reduce costs of medical treatments in commercial feedlots.

Discussion. One problem we found, was that we have relatively high α error, which causes the overall accuracy to be a little bit low. However, the goal of this experiment is to detect sickness as soon as possible, so we accept a lower β level at the expense of a higher α level. The study conducted by Wittum et al. reported that 68% of the cattle with lung lesions at slaughter were not pulled out by pen riders. Our assumption for estimating β and α was that the pen riders always classified correctly but in reality they probably did not. By using the EWMA procedure, we detected more morbid animals than pen riders, which caused the α level to be high. Among those animals, some might be really sick but were not recognized by pen riders. Therefore, our true α level would probably be lower than 0.3148 if we had the correct classification of the animals.

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