Detecting Bovine Lameness Using Three-Dimensional Limb Movement Variable Analysis

UMBC REU Site: Interdisciplinary Program in High Performance Computing

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Introduction

Early detection of lameness is important for dairy farmers to enhance profits and animal welfare. Database consists of lameness score and 76 limb movement variables (LMVs) relating to a cow's gait. Previous work on this project used the TRANSREG procedure in SAS and a binomial (sound/lame) classification. In this project, we create R programs to facilitate exploring a large number of transformations and subsets of LMVs.

Methodology

Logistic regression

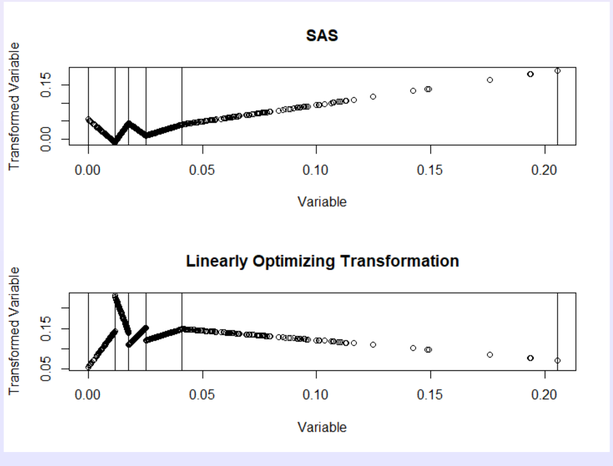
$$P(Lame) = \frac{e^{\beta_0 + \sum(\beta_i * TLMV_i)}}{1 + e^{\beta_0 + \sum(\beta_i * TLMV_i)}}$$

To find piecewise transformations, let **A** be an $n \times (k+2)$ matrix of the form

$$\begin{bmatrix} \vec{x}_1 & \vec{0} & \vec{0} & \dots & \vec{0} & \vec{1} \\ \vec{0} & \vec{x}_2 & \vec{0} & \dots & \vec{0} & \vec{0} \\ \vec{0} & \vec{0} & \vec{x}_3 & \dots & \vec{0} & \vec{0} \\ \dots & \dots & \dots & \dots & \dots & \dots \\ \vec{0} & \vec{0} & \vec{0} & \dots & \vec{x}_{(k+1)} & \vec{0} \end{bmatrix}$$

where n is the number of observations and k is the number of knots.

- Linearly optimized:
$$T\vec{x} = \mathbf{A}(\mathbf{A}^T\mathbf{A})^{-1}\mathbf{A}^T\vec{\mathbf{Y}}$$
- Logistically optimized: apply logistic regression on basis for each variable
- Continuous: constrain intercepts
- Test cubic spline vs. linear spline



Lameness Detection Device

Binomial vs. Multinomial

Binomial (2 classes): lame or sound
Multinomial (3 classes): severely lame, mildly lame, or sound
MC = misclassification

Contingency Table for Binary Classifier

	+	-
Predicted +	TP	MC
Predicted -	MC	TN

Multinomial Contingency Table

	1	2	3
1	True	MC	MC
2	MC	True	MC
3	MC	MC	True

AUC = area under the curve of sensitivity (true positive rate) vs. 1 - specificity (true negative rate). Multinomial AUC can be calculated by

$$\text{AUC}_{\text{total}} = \sum_{c_i \in C} AUC(c_i) * p(c_i)$$

where $AUC(c_i)$ is the AUC of the class and $p(c_i)$ is the prevalence of that class in the dataset.

Acknowledgments

- REU Site: `hpcreu.umbc.edu`
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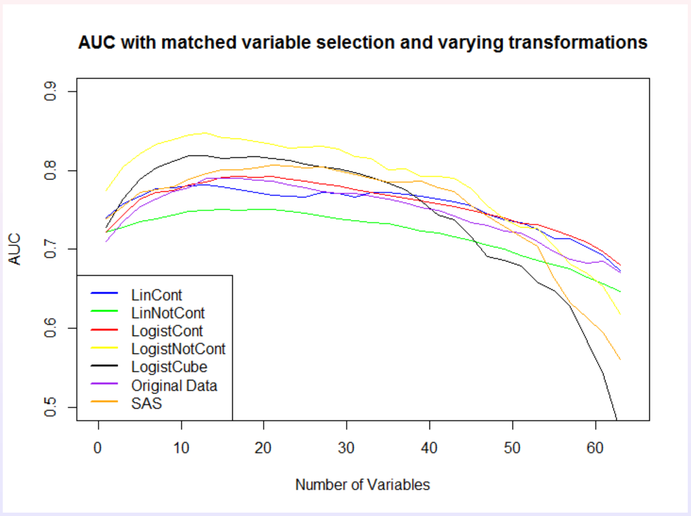
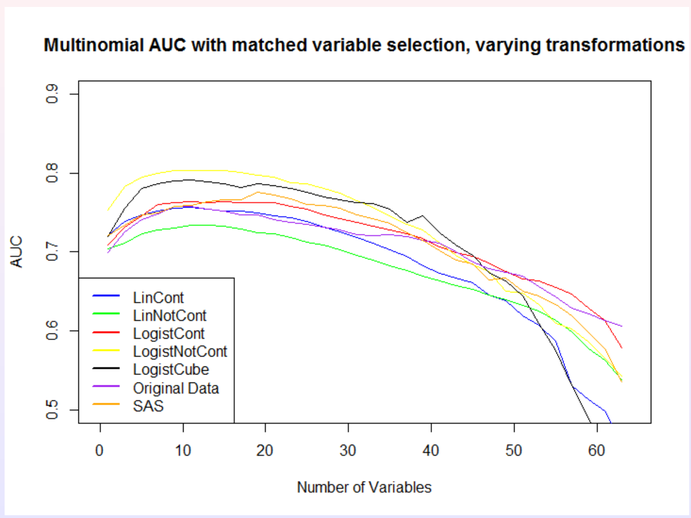
- StepAnalysis LLC

Binomial Classification Results



Multinomial Classification Results



Conclusions

- Logistically optimized transformation achieves higher AUC than TRANSREG procedure [a]
- Multinomial model produces a more specific classification than binomial
- Successfully transitioned code from SAS to open-source R

[a]Pilot Data Set from Dec 2016

References

[1] Dunthorn, J. (2015). Journal of Dairy Research, 82(04), 391-399. doi:10.1017

[2] Fawcett, T. (2005). Science Direct

[3] Full technical report: HPCF–2017–11 `hpcf.umbc.edu` > Publications