MACE For Conformation Traits

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Introduction

Multiple across country evaluations (MACE) for production traits are now routinely computed and used in many countries. However, for conformation traits most countries resort to conversion formulas. Advantages associated with MACE include:

1. Utilization of all information among countries to generate international breeding values.

2. Utilization of a bull's pedigree information as well as his own information.

3. Re-ranking of bulls allowing for possible genotype by environment interaction and differences in trait definition.

4. Simultaneous analysis of proofs from multiple countries.

This paper describes the implementation of MACE for conformation traits in the USA.

Model

The standard model (Schaeffer and Zhang, 1993) for international genetic evaluations was used to analyze the data. This can be represented by:

$$y = C\mu + ZQg + Zs + e$$

where:

y : vector of de-regressed proofs
μ : vector of country effects
g : vector of genetic group effects for phantom parents
s : vector of random sire effects
e : vector of residual effects for de-regressed proofs
C : incidence matrix associating de-regressed proofs with country effects
Z : incidence matrix associating de-regressed with sire proofs
Q : incidence matrix assigning sires to phantom groups

Distributions for the random variables are assumed to be:

$$\begin{pmatrix} y \\ s \\ e \end{pmatrix} \sim MVN\left\{\begin{pmatrix} C\mu + ZQg \\ 0 \\ 0 \end{pmatrix}, \begin{pmatrix} ZGZ^T + R & GZ^T & R \\ & G & 0 \\ symm. & & R \end{pmatrix}\right\}$$

where:

G : is the genetic (co)-variance matrix among elements of s, $G = G_o \otimes A$ where G_o is the genetic (co)-variance matrix among the traits of interest and A is the numerator relationship matrix among the unique animals represented in s
R : is a diagonal matrix with diagonals equal to the ratio of the residual variance in a country divided by the number of daughters in that country

The mixed model equations for the equivalent model described by Quaas (1988) are (Sigurdsson and Banos, 1995):

$$\begin{pmatrix} C^T R^{-1} C & 0 & C^T R^{-1} Z \\ & Q^T A^{-1} Q \otimes G_o^{-1} & -Q^T A^{-1} \otimes G_o^{-1} \\ symm. & & Z^T R^{-1} Z + A^{-1} \otimes G_o^{-1} \end{pmatrix} \begin{pmatrix} \hat{c} \\ \hat{g} \\ Q\hat{g} + \hat{s} \end{pmatrix} = \begin{pmatrix} C^T R^{-1} y \\ 0 \\ Z^T R^{-1} y \end{pmatrix}$$

Implementation

Official conformation data was obtained from Canada (CAN), France (FRA), Germany (DEU), Italy (ITA), The Netherlands (NLD), and the United States (USA). Traits considered were the 12 standard and two optional traits recommended by the committee on the world-wide harmonization of linear type classification (Cnossen et al., 1993), as well as four additional traits, Rear Legs Rear View, Feet and Leg Score, Rear Udder Width, and Final Score (Appendix 1). These last four traits are necessary to determine the USA type and production index (TPI, Holstein Association USA, Inc. 1997). Selection of trait combinations for each of the 18 USA traits was based on correlations of proofs for bulls evaluated in both countries. For each USA trait the foreign trait showing highest proof correlation was chosen. (Appendix 1). In addition to the direct computation of the 18 traits, two composites, udder and feet & legs, were computed based on the MACE of the individual traits in the composite (Holstein Association USA, Inc. 1997).

Edits performed on the data were similar to those used for the production traits by INTERBULL. However, records based on less than 10 daughters, records on bulls not on an official AI testing scheme, or second country proofs based on less than 75 daughters in less than 50 herds were all included as long as the proof was reported in the official type performance file from each country. Records on bulls born before 1980 were eliminated to reduce time period effects (Weigel, 1996).

Phantom parent groups were assigned based on unknown ancestor (sire, maternal grandsire, maternal granddam), year of birth, and country of origin. Birth years were divided into three year intervals.

De-regressed proofs were computed using the de-regression procedure described by Rozzi and Schaeffer (1996). Subsequently (co)-variance matrices G_o were estimated from the de-regressed data using the EM-REML algorithm presented by Klei and Weigel (1998) using information on all bulls in all countries.

MACE solutions were computed through an LU decomposition (Golub and Van Loan, 1987) of the mixed model equations using sparse matrix techniques (FSPAK, Perez-Enciso et al., 1994). Reliabilities of the MACE proofs were obtained by inverting the mixed model equations using FSPAK to obtain the appropriate diagonal elements. Official reliabilities are based on the reliability for PTAT.

Results and Discussion

Appendix I shows the proof correlations for each of the 18 trait combinations. From these tables it can be observed that most of the udder traits measured show high correlations among the countries reflecting great uniformity in observing these traits.

Body traits, except Stature, show high correlations among some of the countries while other countries are moderate to lowly correlation. In this category France has no trait that adequately correlates with Dairy Form (Angularity) and subsequently bulls with only observations in France will have an evaluation based on the US pedigree index for this trait when reported on the USA base.

For feet and legs correlations are, again, high for some for some of the countries while low among others. The only exception among these traits is Rear Leg Side View, one of the standard traits. In this group of traits no corresponding traits could be found for Rear Leg Rear View and Feet and Leg Score in both Germany and France resulting in pedigree indices for bulls with only observations in those countries.

In the USA, Final Score is evaluated as a separate trait. To be consistent with the national evaluation it was decided that this should also be the case with Final Score evaluated in MACE. Correlations for USA Final Score with the overall type traits in the other countries were all higher then .75 and deemed adequate. In situations where countries compute an overall type trait as a composite of linear evaluations this method could be applied.

France only supplied second country proofs on USA bulls. This resulted in a limited number of ties with other countries. Additional data on second country proofs from France for bulls from these countries could boost the proof correlations

Figure 1 through Figure 3 show converted proofs and MACE proofs on ten bulls from three of the countries for Udder Composite. One of the reasons to use a MACE model is that it is a refinement of the method of using conversion formulas. This is well illustrated in Figure 1. From this figure it can be observed that none of these ten bulls change rank, however bulls C and D, which were equal under the conversion method, show differences when using MACE to determine evaluations on foreign bulls.

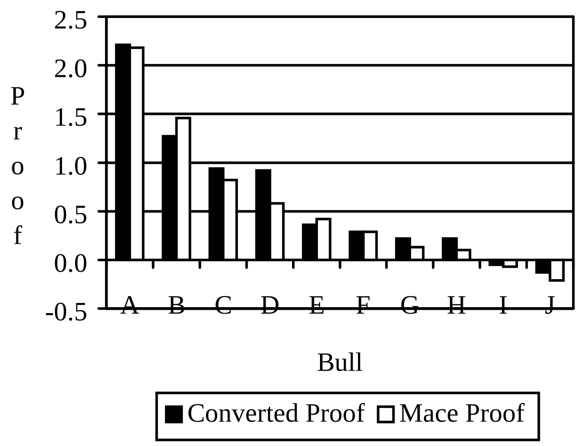

Figure 1. Comparison of converted and MACE proofs for udder composite for 10 bulls from country I.

Figure 2 shows that animals can re-re-rank when using MACE. If selection for udder composite was based on a culling level of +1.00, converted proofs would have recommended the use of bull A through G. MACE, however, would have recommended the use of A through D, G and H. Even though individual differences for these two evaluation methods are not large, selection decisions will be influenced. A similar situation can be observed for country III (Figure 3). Ranking of the top five bulls based on converted proofs would be A, B, C, D, E while using conversion methods, while the ranking when using MACE is B, A, D, C, E.

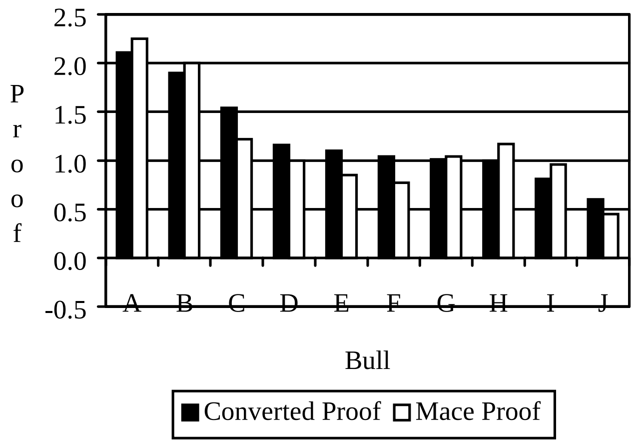

Figure 2. Comparison of converted and MACE proofs for udder composite for 10 bulls from country II.

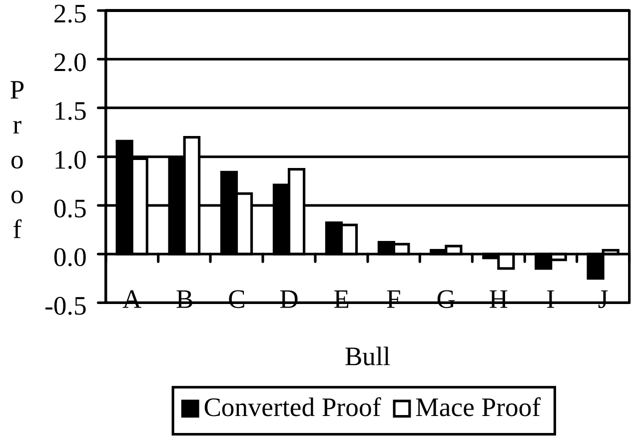

Figure 3. Comparison of converted and MACE proofs for udder composite for 10 bulls from country III.

Conclusions

MACE can be used to compute evaluations for conformation traits. MACE provides a refinement in determining genetic potential of foreign bulls through a refinement of the statistical model used to describe the data. As opposed to conversion methods, MACE allows for the re-ranking of bulls resulting in a modification of selection decisions both when using independent culling levels and when usage of sires is dependent on the proof of the bull.

Acknowledgments

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Appendix I
MACE Correlations For Conformation Traits

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Heritabilities on diagonal

trait	country	USA	CAN	NLD	DEU	ITA	FRA	proof variance
Stature	USA	**.42**	.98	.92	.91	.97	.92	1.35
Stature	CAN		**.40**	.93	.92	.96	.92	28.14
Stature	NLD			**.60**	.95	.92	.95	22.07
Stature	DEU				**.43**	.92	.92	131.00
Stature	ITA					**.38**	.92	1.89
Sacrum Height	FRA						**.47**	1.74

trait	country	USA	CAN	NLD	DEU	ITA	FRA	proof variance
Strength	USA	**.31**	.91	.80	.78	.95	.78	1.29
Chest Width	CAN		**.21**	.67	.66	.89	.79	32.02
Chest Width	NLD			**.30**	.87	.75	.55	17.07
Chest Width	DEU				**.21**	.76	.56	237.11
Strength	ITA					**.31**	.81	1.80
Chest Width	FRA						**.36**	1.26

trait	country	USA	CAN	NLD	DEU	ITA	FRA	proof variance
Body Depth	USA	**.37**	.89	.76	.71	.95	.81	1.12
Capacity	CAN		**.32**	.49	.44	.83	.80	29.02
Body Depth	NLD			**.35**	.86	.81	.57	18.10
Body Depth	DEU				**.31**	.76	.60	201.67
Body Depth	ITA					**.31**	.79	1.73
Chest Width	FRA						**.36**	1.26

trait	country	USA	CAN	NLD	DEU	ITA	FRA	proof variance
Dairy Form	USA	**.29**	.92	.70	.86	.93		1.76
Dairy Character	CAN		**.23**	.69	.83	.87		29.64
Type Milk	NLD			**.30**	.75	.69		18.88
Angularity	DEU				**.32**	.83		152.31
Angularity	ITA					**.30**		1.51
	FRA							

Missing values indicate that no corresponding trait could be determined.

trait	country	USA	CAN	NLD	DEU	ITA	FRA	proof variance
Rump Angle	USA	**.33**	.97	.96	.96	.96	.94	1.85
Pin Setting	CAN		**.30**	.96	.95	.95	.93	32.82
Rump Angle	NLD			**.35**	.95	.95	.95	22.06
Rump Angle	DEU				**.13**	.94	.93	270.79
Rump Angle	ITA					**.25**	.93	2.68
Rump Angle	FRA						**.34**	.88

trait	country	USA	CAN	NLD	DEU	ITA	FRA	proof variance
Rump Width	USA	**.26**	.86	.81	.82	.88	.67	1.39
Pin Width	CAN		**.24**	.83	.79	.87	.66	27.28
Rump Width	NLD			**.30**	.88	.91	.57	22.94
Rump Width	DEU				**.24**	.84	.56	193.66
Thurl Width	ITA					**.29**	.66	1.67
Hip Width	FRA						**.32**	1.16

MACE Correlations For Conformation Traits
Continued

trait	country	USA	CAN	NLD	DEU	ITA	FRA	proof variance
Rear Leg Side View	USA	**.21**	.96	.87	.90	.93	.84	2.50
Rear Leg Set	CAN		**.16**	.88	.90	.92	.84	40.34
Rear Leg Set	NLD			**.35**	..90	.89	.88	23.23
Rear Leg Set	DEU				**.13**	.92	.87	265.38
Legs Side	ITA					**.16**	.87	3.03
Rear Leg Set	FRA						**.07**	1.58

trait	country	USA	CAN	NLD	DEU	ITA	FRA	proof variance
Rear Leg Rear View	USA	**.11**	.59	.67		.68		3.54
Foot Angle	CAN		**.07**	.57		.76		38.13
Feet and Legs	NLD			**.30**		.42		14.31
	DEU							
Foot Angle	ITA					**.18**		2.66
	FRA							

Missing values indicate that no corresponding trait could be determined.

trait	country	USA	CAN	NLD	DEU	ITA	FRA	proof variance
Foot Angle	USA	**.15**	.90	.67	.59	.91	.79	2.24
Foot Angle	CAN		**.07**	.76	.63	.79	.79	38.25
Claw Diagonal	NLD			**.20**	.52	.51	.62	20.37
Foot Angle	DEU				**.13**	.64	.67	254.48
Foot Angle	ITA					**.18**	.76	2.64
Heel Depth	FRA						**.10**	1.35

trait	country	USA	CAN	NLD	DEU	ITA	FRA	proof variance
Feet and Leg Score	USA	**.17**	.84	.70		.71		2.71
Foot Angle	CAN		**.07**	.58		.77		38.98
Feet and Legs	NLD			**.30**		.44		14.38
	DEU							
Foot Angle	ITA					**.18**		2.66
	FRA							

Missing values indicate that no corresponding trait could be determined.

trait	country	USA	CAN	NLD	DEU	ITA	FRA	proof variance
Fore Udder	USA	**.29**	.93	.85	.83	.92	.83	1.71
Fore Attachment	CAN		**.14**	.83	.83	.90	.79	41.01
Fore Udder	NLD			**.35**	.91	.75	.71	24.72
Fore Udder	DEU				**.20**	.81	.76	247.73
Fore Attachment	ITA					**.15**	.85	3.30
Udder Depth	FRA						**.35**	.77

trait	country	USA	CAN	NLD	DEU	ITA	FRA	proof variance
Rear Udder Height	USA	**.28**	.92	.83	.83	.86	.80	1.83
Rear Attachment	CAN		**.19**	.77	.83	.82	.76	30.41
Rear Udder Height	NLD			**.35**	.86	.86	.74	22.26
Rear Udder Height	DEU				**.18**	.82	.72	210.56
Rear Udder Height	ITA					**.20**	.71	2.57
Rear Udder Height	FRA						**.20**	1.11

MACE Correlations For Conformation Traits
Continued

trait	country	USA	CAN	NLD	DEU	ITA	FRA	proof variance
Rear Udder Width	USA	**.23**	.90	.74	.74	.82	.66	1.86
Rear Attachment	CAN		**.15**	.64	.63	.78	.57	35.36
Rear Udder Height	NLD			**.35**	.86	.59	.77	22.49
Rear Udder Height	DEU				**.18**	.60	.71	210.96
Rear Udder Width	ITA					**.23**	.41	1.87
Rear Udder Height	FRA						**.20**	1.12

trait	country	USA	CAN	NLD	DEU	ITA	FRA	proof variance
Udder Cleft	USA	**.24**	.90	.91	.76	.90	.90	1.93
Median Suspensory	CAN		**.15**	.88	.75	.86	.87	31.66
Udder Cleft	NLD			**.25**	.85	.89	.91	19.06
Central Ligament	DEU				**.20**	.82	.80	205.86
Ligament	ITA					**.15**	.91	3.50
Udder Cleft	FRA						**.26**	.86

trait	country	USA	CAN	NLD	DEU	ITA	FRA	proof variance
Udder Depth	USA	**.28**	.91	.97	.93	.97	.96	2.34
Udder Depth	CAN		**.27**	.89	.82	.91	.90	35.62
Udder Depth	NLD			**.45**	.94	.95	.96	22.16
Udder Depth	DEU				**.31**	.92	.92	195.41
Udder Depth	ITA					**.29**	.95	2.23
Udder Depth	FRA						**.35**	.77

trait	country	USA	CAN	NLD	DEU	ITA	FRA	proof variance
Front Teat Placement	USA	**.26**	.94	.89	.90	.91	.89	1.97
Fore Teat Placement	CAN		**.24**	.94	.92	.86	.94	33.9
Teat Placement	NLD			**.45**	.93	.81	.95	20.09
Teat Placement	DEU				**.27**	.82	.91	199.84
Teats Position	ITA					**.22**	.81	2.27
Teat Placement Front	FRA						**.30**	1.14

trait	country	USA	CAN	NLD	DEU	ITA	FRA	proof variance
Teat Length	USA	**.26**	.91	.96	.95	.95	.96	2.34
Fore Teat Length	CAN		**.28**	.93	.91	.87	.92	31.85
Teat Length	NLD			**.45**	.94	.92	.96	25.94
Teat Length	DEU				**.24**	.92	.94	215.35
Teats Length	ITA					**.22**	.93	4.32
Teat Length	FRA						**.30**	1.11

trait	country	USA	CAN	NLD	DEU	ITA	FRA	proof variance
PTAT	USA	**.29**	.87	.78	.76	.85	.78	.81
Conformation	CAN		**.18**	.69	.62	.74	.80	31.60
Final Score	NLD			**.30**	.56	.73	.64	19.52
Body Type	DEU				**.30**	.68	.53	134.68
Final Score	ITA					**.15**	.65	.60
Type Composite	FRA						**.30**	.75