Reliability of ssGBLUP breeding values in routine test-day multi-trait model

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Situation in CZE

- Routine method for prediction of single-step genomic breeding values developed and running
- Officially published traits: test-day milk production, fat (kg, %), protein (kg, %)

- Reliabilities of GEBVs

Routine evaluation

- Test-day milk production (Zavadilova et al., 2005):
  - **Three traits**: 1st, 2nd, 3rd lactation
- Effects:
  - **Herd-Test-Day** (fixed)
  - Legendre polynomials for **lactation*fixed group**
    4 polynomials per each lactation (fixed)
  - **Regressor for days-in milk** for each lactation (fixed)
  - Legendre polynomials for **additive genetic effect of individual animal**:4 within each lactation with covariance matrix among lactations, i.e. 12x12 elements and connected with relationship matrix (random)
  - Legendre polynomials for **permanent environmental effect** of individual animal:4 within each lactation with covariance matrix among lactations, i.e. 12x12 elements (random)

Routine evaluation

- Single-step GBLUP:
  - **H**: 20% **A** , 80% **G** (Aguilar et al., 2010)
  - **G:**
    - Normalised (aver. diag. = 1) (Forni et al., 2011)
    - Shifted (aver. **G** = aver. $\mathbf{A_{22}}$) (Vitezica et al., 2011)

Reliability of GEBV - data

- 20,220,047 test-day milk production records of 1,126,102 Czech Holstein cows
- 1,844,679 animals in the pedigree
- 2,236 genotyped bulls; 1,791 with >3 offspring
- Illumina BovineSNP50 Beadchip V2

Reliability of GEBV - method

- Misztal et al. 2013:
  - Approximation of reliability (R^2) of ssGBLUP GEBVs
- Strabel et al. 2001:
  - Approximation of R^2 in multi-trait evaluation
- Misztal et al. 1991:
  - Approximation of R^2 with permanent environmental effect in traits with multiple observations
- Effective number of records (ENR)

Reliability of GEBV - method

- Each trait separately:
  - 1. Approximation of R^2 of BLUP EBVs on the basis of effective number of records
  - 2. Calculation of the reliability of genotyped animals (additional genomic information)
  - 3. Addition of the contribution of genotyping to the reliabilities of non-genotyped animals.
- Multi-trait evaluation:
  - 4. Re-evaluation of individual reliabilities due to the covariances among traits (multi-trait model)

Reliability of GEBV – BLUP

- **1. Approximation of R^2 of BLUP EBVs on the basis of effective number of records**
  - Calculation of ENR for each animal and iterative procedure for taking into account the relationships of animals (Misztal et al., 1993)
  - The effective number of records **d** for each animal was updated by the formula: $\mathbf{d}^* = \tau^* \mathbf{d} / (\tau + \mathbf{d})$ (Misztal et al., 1991) where τ is the ratio of residual variance to permanent environmental variance

Reliability of GEBV – ssGBLUP

- **2. Calculation of the reliability of genotyped animals (additional genomic information)**

  – Reliability $r^2_i = 1 - \alpha\, q^{ii}$

  α - ratio of error variance to animal genetic variance

  q_{ii} - the diagonal elements of the $\mathbf{Q}^{-1}$ matrix:

  $$\mathbf{Q}^{-1} = [\mathbf{D} + (\mathbf{I} + \mathbf{G}^{-1} - \mathbf{A}_{22}^{-1})\,\alpha]^{-1}$$

  D - contribution of the records and pedigrees to the reliability from step (1)

  I - identity matrix

  $\mathbf{G}^{-1}$ - inverse of the genomic relationship matrix

  $\mathbf{A}_{22}^{-1}$ - inverse of the section of the pedigree-based relationship matrix that contains relationship information from only the genotyped animals

(Misztal et al., 2013)

Reliability of GEBV – ssGBLUP

- **3. Addition of the contribution of genotyping to the reliabilities of non-genotyped animals**.

  - Procedure similar to the step (1) of the method

  - The reliabilities of the genotyped bulls kept constant:
    - to avoid double counting the contribution of the relationships among these bulls
    - to avoid changing the already fully conveyed values.

Reliability of GEBV – MT-ssGBLUP

- **4. Re-evaluation of individual reliabilities due to the covariances among traits (multi-trait model)**

  – Taking into account the additive genetic covariances among traits

  – $r_i^2 = 1 - (\widehat{C}^{-1}) / (\mathbf{G_0})$

  $\mathbf{G_0}$ - variance covariance matrix of the additive genetic effect

  $\widehat{C}^{-1}$ **-** inversion of the approximation of the left-hand side of the mixed-model equations for the animal and its progeny

  (Strabel et al., 2001)

Reliability of GEBV - method

- **Three lactation index for routine publication:**

  - Reliability = $(\mathbf{b}`\mathbf{P}\mathbf{b}) / (\mathbf{a}`\mathbf{G}_T\mathbf{a})$

    b - vector of weights in index for three lactations

    P - covariance matrix of breeding values

    a - vector of weights of genetic values (1/3 each trait)

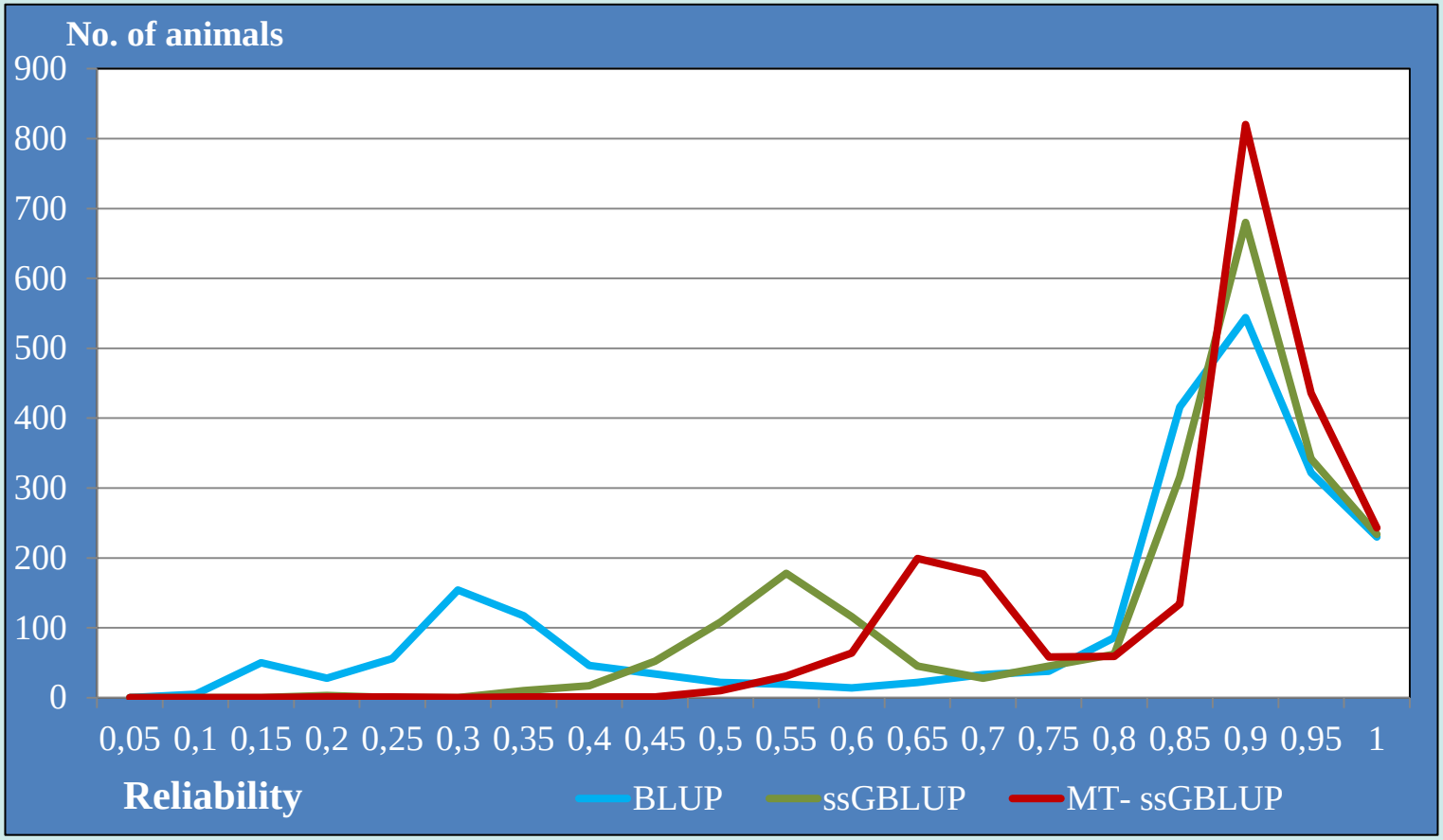
    $\mathbf{G}_T$ - genetic covariance matrix among lactations

Reliability of GEBV - results

R^2 values for:	Step of method	No. of animals	1st lactation mean	1st lactation s.d.	2nd lactation mean	2nd lactation s.d.	3rd lactation mean	3rd lactation s.d.	3-lactation index mean	3-lactation index s.d.
Whole population	BLUP	1,854,275	.410	.142	.376	.135	.339	.126	.595	.157
Genotyped young	BLUP	445	.297	.078	.266	.084	.241	.083	.484	.105
Genotyped proven	BLUP	1,791	.871	.120	.806	.174	.720	.208	.907	.087
Whole population	ssGBLUP	1,854,275	.411	.142	.376	.135	.340	.125	.596	.157
Genotyped young	ssGBLUP	445	.530	.063	.493	.064	.436	.070	.712	.053
Genotyped proven	ssGBLUP	1,791	.888	.092	.839	.128	.765	.158	.925	.061
Whole population	MT-ssGBLUP	1,854,275	.478	.154	.486	.156	.459	.148	-	-
Genotyped young	MT-ssGBLUP	445	.652	.051	.673	.051	.633	.052	-	-
Genotyped proven	MT-ssGBLUP	1,791	.907	.072	.894	.075	.852	.088	-	-

Reliability of GEBV - results

Number of genotyped bulls by reliability of EBV/GEBV in different parts of procedure:
1st Lactation



Reliability of GEBV - results

- GEBVs and reliabilities are continually published at http://www.plemdat.cz

National genomics evaluation (22.01.2015)

Search (yellow cells): search

Records on page: 40

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state reg	name	born	sire name	MGS name	daughters	herds	R	milk	kg fat	% fat	kg prot	% prot	SCC daugh.	SCC herds	SCC	bull ID
NGA-665	PEIRAK	2011	ARDEN	ALTAOLIVER	00000	0000	69	+1030	+039	-0.12	+036	+0.00	00000	0000	107	CZEM000762777061
RED-587	JEGO	2010	JERUDO	GOLDWYN	00000	0000	71	+0146	+027	+0.26	+015	+0.16	00000	0000	112	NLDM000569744953
RED-588	ORVIL	2010	DESTRY	ADVENT-RED	00000	0000	63	-0179	+006	+0.20	-006	+0.00	00000	0000	107	NLDM000745729369
RED-591	OJ	2010	DESTRY	CLASSIC	00000	0000	64	+0012	-002	-0.04	+002	+0.02	00000	0000	108	NLDM000571011333
RED-596	PARMA	2010	MITEY-P	BURKET-FALLS PER	00000	0000	51	-0180	+005	+0.18	+000	+0.10	00000	0000	110	DEUM000353649969
RED-597	SHAWNEE	2010	CHRIS	MR BURNS	00000	0000	61	+0265	+011	-0.03	+007	-0.03	00000	0000	098	USAM000688871604
RED-598	MAICON	2010	JERUDO	KIAN	00000	0000	73	+0004	+024	+0.32	+013	+0.22	00000	0000	108	NLDM000716666549
RED-600	ARAM	2011	AWARD	FICTION	00000	0000	62	+0192	+013	+0.04	+012	+0.09	00000	0000	112	NLDM000543311971
RED-601	DEPUTY	2011	IDEAL	LAWN BOY P-RED	00000	0000	59	+0149	+010	+0.03	+014	+0.14	00000	0000	100	NLDM000543312099
RED-602	BISTRO RED	2011	AXION-RED	ONWARD	00000	0000	64	+0117	+007	+0.01	+004	+0.00	00000	0000	097	CANM000106888992
RED-603	SEVEN	2011	RIVERLAND FIDJI	ARNOLD	00000	0000	57	+0720	+026	-0.09	+026	+0.02	00000	0000	101	NLDM000544270541
RED-606	FIRE-RED	2010	FIDELITY	LIGHTNING	00000	0000	65	-0086	+022	+0.36	+016	+0.32	00000	0000	094	BELM000010220998
RED-612	XAVI RED	2012	ALCHEMY	MR BURNS	00000	0000	58	+0378	+014	-0.05	+018	+0.08	00000	0000	102	NLDM000539346589
RED-613	FAGENO	2012	RIVERLAND FIDJI	IDEVRA RUB.RUACA	00000	0000	60	+0358	+032	+0.20	+019	+0.10	00000	0000	099	DEUM000120551058
RED-614	ATOMIUM RED	2012	DETOX	ALTABAXTER	00000	0000	63	+0468	+036	+0.17	+016	+0.00	00000	0000	096	CANM000107640201
RED-615	DOMINANT	2011	MAN-O-MAN	SHOTTLE	00000	0000	63	+0537	+045	+0.25	+027	+0.12	00000	0000	104	USAM000070346535
RED-622	DESIGN	2010	DESTRY	LIGHTNING	00000	0000	63	-0232	+017	+0.40	+002	+0.17	00000	0000	097	NLDM000690612262
RED-623	ALTAMR P-RED	2011	COLT P RED	GOLDWYN	00000	0000	64	+0090	+001	-0.05	+005	+0.02	00000	0000	100	USAM000070826950
RED-625	ALCHEMIST	2012	ALCHEMY	LAWN BOY P-RED	00000	0000	54	+0266	+009	-0.05	+011	+0.03	00000	0000	108	DEUM000537652863
RED-628	LAKE-RED	2012	LADD P RED	SUPER	00000	0000	60	+0393	+016	-0.04	+016	+0.04	00000	0000	111	DEUM000356348098
RED-629	MAINSTREET	2012	MAICON	FIDELITY	00000	0000	62	+0130	+024	+0.24	+019	+0.24	00000	0000	103	NLDM000871281041
RED-632	ROWAN RED	2012	ALCHEMY	ACME	00000	0000	51	+0104	+013	+0.10	+006	+0.03	00000	0000	108	GBRM387397300309
RED-633	DRAKE	2013	KINGS-RANSOM O D	FIDELITY	00000	0000	54	+0079	+035	+0.41	+019	+0.27	00000	0000	092	DEUM000537808155
RED-634	HETOX RED	2012	DETOX	ALTABAXTER	00000	0000	67	+0176	+023	+0.19	+009	+0.04	00000	0000	100	FRAM005940304611
RED-637	ADDICTION P RED	2012	LADD P RED	GOLDWYN	00000	0000	55	+0022	+012	+0.14	+003	+0.03	00000	0000	105	USAM000072128091
RED-642	BAMA-RED	2010	DESTRY	ALTABAXTER	00000	0000	61	+0122	+024	+0.24	+005	+0.01	00000	0000	106	USAM003006988837
NXA-932	OPAL	2010	PLANET	RAMOS	00003	0003	69	+0736	+029	-0.08	+028	+0.03	00002	0002	092	CZEM000599214071
NXA-934	OTHELO	2010	FIBRAX	SHOTTLE	00000	0000	67	+0539	+026	+0.01	+022	+0.06	00000	0000	093	CZEM000625812053
NXA-976	OSCO	2010	SUPER	GOLDWYN	00000	0000	69	+0786	+012	-0.31	+024	-0.04	00000	0000	106	DEUM001265237674
NXA-977	FANGIO	2010	PLANET	MASCOL	00000	0000	74	+0724	+044	+0.11	+034	+0.13	00000	0000	107	GBRM161428601575

Reliability of GEBV - plans

- Compare the approximate reliabilities with predictions of GEBVs given the truncated data

- Compare the approximated reliability values with results of simulations

Reliability of GEBV

Thank you

for your attention