Alternative consideration of social interaction models in animal breeding

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IRTA, Barcelona, Spain
In general, animals are reared in groups.

Social interactions generates positive (cooperation) or negative (competition) effects

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In general, animals are reared in groups.

In classical breeding programs the social interactions are ignored.

Social interactions between individuals generate an additional level of heritable variation in socially affected traits. (Bijma and Wade, 2008; Bijma, 2010).

Social effects could affect the direction or magnitude of selection response.
In general, animals are reared in groups.

In classical breeding programs the social interaction are ignored.

Social interactions between individuals generate an additional level of heritable variation (Griffing, 1967; Bijma and Wade, 2008).

Social effects could affect the direction or magnitude of selection response.

**But**

**Difficulties associated to social interaction models**

- Collinearity between direct and social genetic effects (Chen et al., 2009; Cantet and Cappa, 2008).
- Collinearity between pen and social effects (Chen et al., 2009; Cantet and Cappa, 2008).
- Lower than expected response to selection (Ellen et al., 2014).
Efforts are needed to improve the implementation of social model

Alemu et al. (2014 and 2016)

Degree of interaction

Social interactions didn’t vary between related versus unrelated mink

Family members

Unrelated individuals

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Could feeding behavior traits help to improve the performance of social interaction models?

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Feeding behavior traits:

- **Feeding rate** (FR)
  
  Feed intake per minute

- **Number of visits** (NV)
  
  Number of visits to the feeder per day

- **Occupation time** (OT)
  
  Minutes in the feeder per day

- **Time between consecutive visits** (INT)
The Duroc line database from 1991 to 2016 shows improvements in:
- Prolificacy
- Body weight at 180 days
- Backfat thickness

(Tibau et al., 1990)

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Minimum</th>
<th>Maximum</th>
<th>SD</th>
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<tbody>
<tr>
<td>Initial age</td>
<td>71.48</td>
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<tr>
<td>Final age</td>
<td>175.3</td>
<td>103</td>
<td>197</td>
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</tr>
<tr>
<td>Number of animal per pen</td>
<td>11.9</td>
<td>7</td>
<td>14</td>
<td>1.65</td>
</tr>
<tr>
<td>Average daily gain (ADG, kg/d)</td>
<td>0.84</td>
<td>0.50</td>
<td>1.07</td>
<td>0.10</td>
</tr>
</tbody>
</table>

SD: Standard deviation
Social model with equal degree of interaction (SAM)

\[ y = Xb + Z_p p + Z_a a_D + Z_s a_S + e \]

The elements of \( Z_s \) are 1 for each pair of animals sharing the same pen and 0 if not.

Social model with a variable degree of interaction (SAM_1)

\[ y = Xb + Z_p p + Z_a a_D + C_s a_{S1} + e \]

The elements of \( C_s \) are the specific degree of interaction between each pair of animals sharing the same pen and 0 if not.

**Batch number (6 levels)**

- 1
- 2
- 3
- 4
- 5
- 6

**Initial age (covariate)**

- 1
- 2
- 3
- 4
- 5
- 6

**Final age (covariate)**

- 1
- 2
- 3
- 4
- 5
- 6

**Number of piglets per pen (random effect)**

<table>
<thead>
<tr>
<th>Pen</th>
<th>Number of Piglets</th>
</tr>
</thead>
<tbody>
<tr>
<td>P1</td>
<td>1</td>
</tr>
<tr>
<td>P2</td>
<td>2</td>
</tr>
<tr>
<td>P3</td>
<td>3</td>
</tr>
<tr>
<td>P4</td>
<td>4</td>
</tr>
</tbody>
</table>

**Pen number**

- P1
- P2
- P3
- P4

**Diagram**

- Pen 1 (P1)
- Pen 2 (P2)
- Pen 3 (P3)
- Pen 4 (P4)

**Variables**

- \( d \)
- \( s \)
- \( a_d \)
- \( a_s \)
- \( a_{d_s} \)

**Equation**

\[ P_i = a_{d_i} + \sum_{j=1}^{n} d_{ij} * s_j + e_i \]
Degree of social interaction

Using one behavior trait (FR or NV or OT or INT):

\[ d_{ij} = \sqrt{(y_i - y_j)^2} \]

where \( y_i \) is the record of animal i for the feeding behavior trait animal and \( y_j \) is the record of the behavior trait of animal j.

Using index of all behavior traits

\[ d_{ij} = \sqrt{(\text{FR}_i - \text{FR}_j)^2 + (\text{NV}_i - \text{NV}_j)^2 + (\text{OT}_i - \text{OT}_j)^2 + (\text{INT}_i - \text{INT}_j)^2} \]

The typical element of \( C_s \) would be

\[ c_{ij} = \frac{d_{ij} - \bar{\mu}_d}{\bar{\sigma}_d} \]
Social model with a variable degree of interaction (\textit{SAM}_i) parameters

\[ TBV_i = a_i + c(n - 1)s_i \]

\[ \sigma^2_{TBV} = \sigma^2_{a_d} + 2c(n - 1)\sigma_{a_d,a_s} + c^2(n - 1)^2\sigma^2_{a_s} \]

\[ \sigma^2_P = \sigma^2_a + c^2(n - 1)\sigma^2_s + 2rc(n - 1)\sigma_{a,s} + rc^2(n - 1)(n - 2)\sigma^2_s + \sigma^2_e \]

\[ T^2_2 = \frac{\sigma^2_{TBV}}{\sigma^2_P} \]

where \( P \neq TBV + e \)

\text{(Duijvesteijn et al., 2012)}
## Genetic parameters

<table>
<thead>
<tr>
<th></th>
<th>AM</th>
<th>SAM</th>
<th>SAM\textsubscript{FR}</th>
<th>SAM\textsubscript{NV}</th>
<th>SAM\textsubscript{OT}</th>
<th>SAM\textsubscript{INT}</th>
<th>SAM\textsubscript{ALL}</th>
</tr>
</thead>
<tbody>
<tr>
<td>$h^2 / T^2$</td>
<td>0.47(0.15)</td>
<td>0.52(0.29)</td>
<td>0.51(0.14)</td>
<td>0.55(0.13)</td>
<td>0.53(0.14)</td>
<td>0.53(0.14)</td>
<td>0.53(0.12)</td>
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<tr>
<td>$T^2_{q1}$</td>
<td>-</td>
<td>-</td>
<td>0.51(0.18)</td>
<td>0.75(0.20)</td>
<td>1.29(0.25)</td>
<td>0.65(0.20)</td>
<td>1.24(0.30)</td>
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<tr>
<td>$T^2_{q3}$</td>
<td>-</td>
<td>-</td>
<td>0.72(0.22)</td>
<td>0.53(0.19)</td>
<td>0.53(0.21)</td>
<td>0.68(0.22)</td>
<td>0.33(0.19)</td>
</tr>
<tr>
<td>$r_{g_{a,s}}$</td>
<td>-</td>
<td>-0.39(0.47)</td>
<td>0.31(0.28)</td>
<td>-0.33(0.48)</td>
<td>-0.41(0.21)</td>
<td>0.11(0.31)</td>
<td>-0.65(0.24)</td>
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</table>
# Genetic parameters

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<td>0.11(0.31)</td>
<td>-0.65(0.24)</td>
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</tbody>
</table>
### Fit quality – Predictive ability

<table>
<thead>
<tr>
<th></th>
<th>AM</th>
<th>SAM</th>
<th>SAM\textsubscript{FR}</th>
<th>SAM\textsubscript{NV}</th>
<th>SAM\textsubscript{OT}</th>
<th>SAM\textsubscript{INT}</th>
<th>SAM\textsubscript{ALL}</th>
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<tbody>
<tr>
<td>DIC</td>
<td>1402.07</td>
<td>1348.69</td>
<td>1376.08</td>
<td>1338.59</td>
<td>1304.74</td>
<td>1330.77</td>
<td>1321.54</td>
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<tr>
<td>Pred. Accuracy</td>
<td>0.521</td>
<td>0.530</td>
<td>0.539</td>
<td>0.552</td>
<td>0.561</td>
<td>0.492</td>
<td>0.540</td>
</tr>
</tbody>
</table>

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7.7% 5.7%
### Percentage of coincidence between top 10% animals

<table>
<thead>
<tr>
<th></th>
<th>EBV&lt;sub&gt;animal&lt;/sub&gt;</th>
<th>TBV&lt;sub&gt;CONST&lt;/sub&gt;</th>
<th>TBV&lt;sub&gt;FR&lt;/sub&gt;</th>
<th>TBV&lt;sub&gt;NV&lt;/sub&gt;</th>
<th>TBV&lt;sub&gt;OT&lt;/sub&gt;</th>
<th>TBV&lt;sub&gt;INT&lt;/sub&gt;</th>
<th>TBV&lt;sub&gt;ALL&lt;/sub&gt;</th>
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<tbody>
<tr>
<td><strong>EBV&lt;sub&gt;animal&lt;/sub&gt;</strong></td>
<td>-</td>
<td>0.70</td>
<td>0.79</td>
<td>0.89</td>
<td>0.44</td>
<td>0.76</td>
<td>0.52</td>
</tr>
<tr>
<td><strong>TBV&lt;sub&gt;CONST&lt;/sub&gt;</strong></td>
<td>-</td>
<td>-</td>
<td>0.68</td>
<td>0.68</td>
<td>0.41</td>
<td>0.58</td>
<td>0.52</td>
</tr>
<tr>
<td><strong>TBV&lt;sub&gt;FR&lt;/sub&gt;</strong></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.83</td>
<td>0.39</td>
<td>0.79</td>
<td>0.59</td>
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<tr>
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<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.41</td>
<td>0.83</td>
<td>0.62</td>
</tr>
<tr>
<td><strong>TBV&lt;sub&gt;OT&lt;/sub&gt;</strong></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.44</td>
<td>0.48</td>
<td>-</td>
</tr>
<tr>
<td><strong>TBV&lt;sub&gt;INT&lt;/sub&gt;</strong></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.41</td>
<td>-</td>
<td>0.65</td>
</tr>
<tr>
<td><strong>TBV&lt;sub&gt;ALL&lt;/sub&gt;</strong></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.41</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
Conclusions

- Including social genetic effects improves DIC compared to classical animal model.

- Using specific levels of interaction for each pair of animals improves the accuracy of the estimation of genetic parameters.

- Some small differences between $\text{SAM}_i$ models with regard to DIC and prediction ability were found, favoring $\text{SAM}_{NV}$, $\text{SAM}_{OT}$ and $\text{SAM}_{ALL}$.

- Genetic ranks vary with the model of analysis.

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Thank you so much for your attention
Why will these traits be used?

- In pigs, the feeding time and feeding rate are correlated with the competition between animals (Nielsen et al., 1995).

- In goat, the animals in high social rank tended to have higher feeding time and lower times in queuing than goats in the animals in medium and low rank category (Shinde et al., 2004; Jørgensen et al., 2007).

- In cows, in the high social ranking (actor) group spent a significantly greater time at the feeder compared to cows in the low-ranking and the correlation between the displacements initiated and social position of the individual were highly significantly (Val-Laillet et al., 2008)
### Material and Methods

**Daily occupation time database (seconds / hour)**

<table>
<thead>
<tr>
<th>ID</th>
<th>Pen</th>
<th>batch</th>
<th>H2</th>
<th>H3</th>
<th>H4</th>
<th>H5</th>
<th>H6</th>
<th>H7</th>
<th>H8</th>
<th>H9</th>
<th>H10</th>
<th>H11</th>
<th>H12</th>
<th>H13</th>
<th>H14</th>
<th>H15</th>
<th>H16</th>
<th>H17</th>
<th>H18</th>
<th>H19</th>
<th>H20</th>
<th>H21</th>
<th>H22</th>
<th>H23</th>
<th>H24</th>
<th>ID Date control</th>
</tr>
</thead>
<tbody>
<tr>
<td>3921</td>
<td>LACT-1-5</td>
<td>LACT-1</td>
<td>5.87</td>
<td>5.93</td>
<td>4.01</td>
<td>3.34</td>
<td>6.45</td>
<td>12.00</td>
<td>11.66</td>
<td>15.29</td>
<td>7.54</td>
<td>8.32</td>
<td>7.99</td>
<td>5.27</td>
<td>3.98</td>
<td>8.69</td>
<td>3.74</td>
<td>7.85</td>
<td>11.58</td>
<td>15.77</td>
<td>7.78</td>
<td>5.96</td>
<td>5.43</td>
<td>3.71</td>
<td>28/04/2013</td>
<td></td>
</tr>
<tr>
<td>3924</td>
<td>LACT-1-8</td>
<td>LACT-1</td>
<td>4.54</td>
<td>4.75</td>
<td>4.51</td>
<td>4.62</td>
<td>4.91</td>
<td>12.89</td>
<td>13.46</td>
<td>12.03</td>
<td>12.06</td>
<td>5.13</td>
<td>6.84</td>
<td>9.08</td>
<td>10.43</td>
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<td>14.82</td>
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<td>3.14</td>
<td>3.64</td>
<td>2.78</td>
<td>05/05/2011</td>
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</tr>
</tbody>
</table>

**Average across days within animal (min / hour)**

Average across days within animal (min / hour)

**The total daily occupation time**

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### The total daily occupation time

<table>
<thead>
<tr>
<th>ID</th>
<th>H1</th>
<th>H2</th>
<th>H3</th>
<th>H4</th>
<th>H5</th>
<th>H6</th>
<th>H7</th>
<th>H8</th>
<th>H9</th>
<th>H10</th>
<th>H11</th>
<th>H12</th>
<th>H13</th>
<th>H14</th>
<th>H15</th>
<th>H16</th>
<th>H17</th>
<th>H18</th>
<th>H19</th>
<th>H21</th>
<th>H22</th>
<th>H23</th>
<th>H24</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>3921</td>
<td>9.50</td>
<td>5.87</td>
<td>5.93</td>
<td>4.01</td>
<td>3.34</td>
<td>6.45</td>
<td>12.00</td>
<td>11.66</td>
<td>15.28</td>
<td>7.54</td>
<td>8.32</td>
<td>7.99</td>
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<td>3.98</td>
<td>8.69</td>
<td>3.74</td>
<td>7.85</td>
<td>11.58</td>
<td>15.77</td>
<td>7.78</td>
<td>5.96</td>
<td>5.43</td>
<td>3.71</td>
<td><strong>164.65</strong></td>
</tr>
<tr>
<td>3924</td>
<td>2.71</td>
<td>4.54</td>
<td>4.75</td>
<td>4.51</td>
<td>4.62</td>
<td>4.91</td>
<td>12.89</td>
<td>13.46</td>
<td>12.03</td>
<td>12.06</td>
<td>5.13</td>
<td>6.84</td>
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<td>9.84</td>
<td>16.21</td>
<td>14.82</td>
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<td>3.14</td>
<td>3.64</td>
<td>2.78</td>
<td><strong>164.70</strong></td>
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<tr>
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<td>9.81</td>
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<td>5.83</td>
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<td>12.50</td>
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<td>12.91</td>
<td>12.45</td>
<td>13.28</td>
<td>13.79</td>
<td>15.47</td>
<td>5.74</td>
<td>3.37</td>
<td>4.50</td>
<td>5.09</td>
<td><strong>165.82</strong></td>
</tr>
</tbody>
</table>

The total daily occupation time was used to calculate the specific level of competition between each pair of animals sharing the same pen.

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Results and discussion

The correlations between the rank of the animals every two consecutive weeks according to each variable

<table>
<thead>
<tr>
<th>Social Trait</th>
<th>Correlation between ranks on social traits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed rate (g/min)</td>
<td>0.70 to 0.80</td>
</tr>
<tr>
<td>Feeding frequency (visits/day)</td>
<td>0.72 to 0.97</td>
</tr>
<tr>
<td>Occupation time (min/day)</td>
<td>0.69 to 0.83</td>
</tr>
<tr>
<td>Time between visits(hour)</td>
<td>0.71 to 0.80</td>
</tr>
</tbody>
</table>

- No much change in social ranks of animals during the fattening period
- These variables can show the social interaction between animals

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Comparison between used models

A) The determinant of Fisher Information Matrix \(I(\theta)\) where the best model is that maximizing the determinant of \(I(\theta)\).

B) The accuracy of the estimates with examining the standard deviation (SD) of genetic parameters.

C) The deviance Information Criterion (DIC).

D) Cross validation.

E) The percentage of coincidence between top 10% of the population depend on TBV.

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$T^2$ as a function of number of mates, relationship between them and social distance (according to overall index)
$\tau^2$ as a function of number of mates and relationship between them.
Conclusions

- Feeding behavior traits could be useful to measure the social interaction between animals sharing a pen.

- Include social effects in analysis models improve DIC of the social models compared with classical animal model.

- Using specific level of competition for each pair of animals improve the accuracy of the estimation of genetic parameters and $|I(\theta)|$.

- The degree of competition between each pair of animals, numbers of animal per pen and relatedness between group members affect the estimated values of $T^2$.

- Genetic ranks greatly vary with the model of analysis.

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