Faculty of Agricultural and Nutritional Sciences

Christian-Albrechts-Universität zu Kiel
Institut für Tierzucht und Tierhaltung

Integrating parameters to assess animal welfare using multicriteria decision analysis

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Introduction

Animal welfare is a multidimensional concept (FAWC, 1992)

Overall assessment of animal welfare (Boutreau et al., 2007a,b; Spoolder et al., 2003)

- **Interactions between dimensions (e.g. compensation)**
- **Choice of parameters (e.g. feasibility, validity, interactive effects)**
- **Relative weighting**
- **Aggregation (e.g. ordinal, cardinal scale)**

Objective

- **Application of Multicriteria Decision Making (MDM) using fuzzy integrals**
- **MDM concern important issues relevant to multidimensional evaluation (aggregation, importance, interaction)**

General concept

The multicriteria decision problem (Grabisch, 1996)

Set of alternatives $\Omega = \{\omega_1, \varpi_2, \ldots, \omega_p\}$

Set of criteria $x = \{x_1, x_2, \ldots, x_n\}$

Set of uni-dimensional weighting functions $u = \{u_1, u_2, \ldots, u_n\}$

Aggregation $u(x_1, \ldots, x_n) = \mathrm{H}(u_1(x_1), \ldots, u_n(x_n))$

Requirements on the aggregation operator (e.g.)

mathematical	**behavioural**
extremal values	possibility of expressing weights on criteria
idempotence	possibilty of expressing the behaviour of the DM
continuity	possibility of expressing compensation or interaction
monotonicity	
decomposability	

General concept

Fuzzy measures and integrals **(Grabisch, 1996)**

A fuzzy measure on the set X **of criteria is a set function** $\mu : P(x) \rightarrow [0,1]$ **satisfying the following axioms.**

(i) $\mu(\phi) = 0, \mu(X) = 1$

(ii) $A \subset B \subset X$ implies $\mu(A) \leq \mu(B)$

The Choquet integral of function $f : X \rightarrow [0,1]$ **with respect to** μ

$$C_\mu(f(x_1),\ldots,f(x_n)) := \sum_{i=1}^{n} (f(x_{(i)}) - f(x_{(i-1)}))\mu(A_{(i)})$$

General concept

Shapley value **(Murofushi, 1992)**

Shapley value expresses the relative importance of a single criterion into the decision problem.

It is convenient to scale these values by the number of criteria, so that a Shapley value > 1 indicates an attribute more important than the average

Interaction index

Interaction index between two criteria ranges in $[-1,1]$

Negative values indicate redundancy (compensation), positive values synergy.

Example – data

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Farms (A, B, C, D, E)

Criteria

- Housing (X_1;1, …, 5)
- Feeding (X_2;0,…, 3)
- Behaviour (X_3;0,…, 3)
- Health (post mortem abnormalities; X_4 ;0, …, 100%)

Farm	Housing	Feeding	Behaviour	Health
A	5	3	2	75
B	4	2	2	25
C	5	1	1	5
D	2	0	2	25
E	3	3	1	25

Example – utility, transformation

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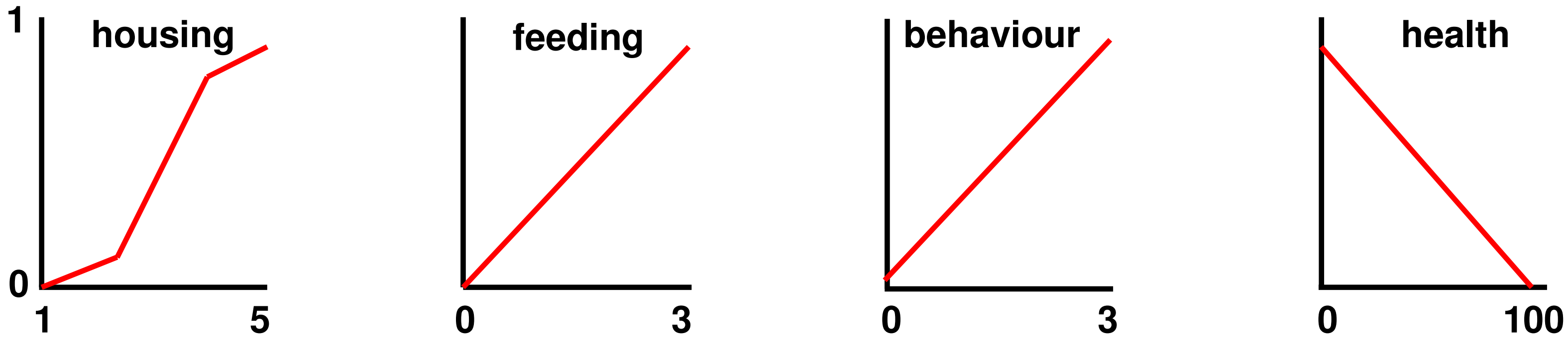
Utility function



Linear-Scale-Transformation (0,1)

Criteria to maximise
$$r_{ij} = \frac{x_{ij} - x_j^{\min}}{x_j^{\max} - x_j^{\min}}$$

Criteria to minimise
$$r_{ij} = \frac{x_j^{\max} - x_{ij}}{x_j^{\max} - x_j^{\min}}$$

best alternative $r_{ij} = 1$

Example – aggregation

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Weighted arithmetic mean (w.a.m.)

μ(housing) = μ(health) = 3; μ(feeding) = μ(behaviour) = 2;

Farm	Housing	Feeding	Behaviour	Health	w.a.m.
A	1.000	1.000	0.750	0.250	0.725 (3)
B	0.750	0.750	0.750	0.750	0.750 (2)
C	1.000	0.625	0.500	1.000	0.825 (1)
D	0.250	0.500	0.750	0.750	0.550 (5)
E	0.375	1.000	0.500	0.750	0.638 (4)

Shapley value (normalised)

	Housing	Feeding	Behaviour	Health
	1.056	0.934	0.862	1.147

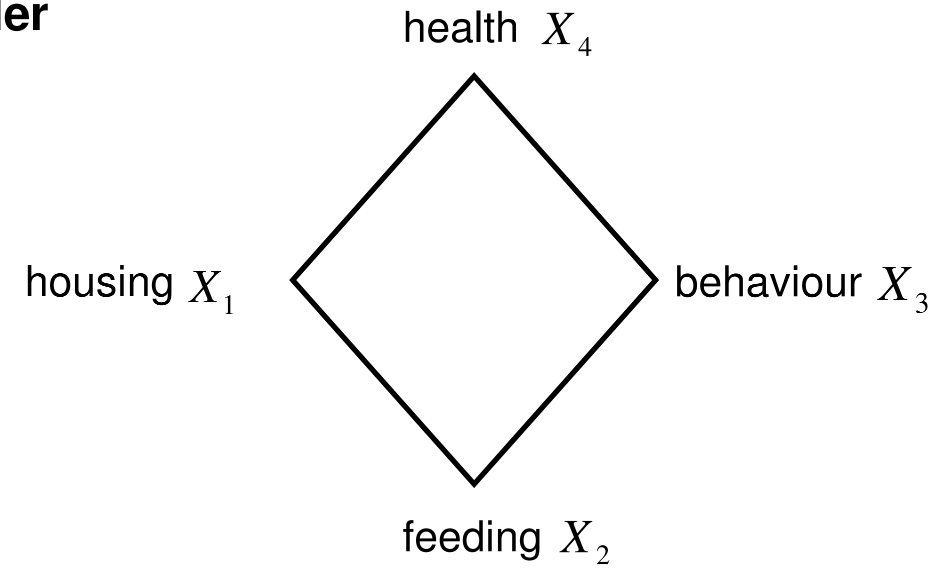
Interaction index

	Feeding	Behaviour	Health
Housing	-0.046	0.001	0.097
Feeding		0.030	0.015
Behaviour			-0.018

Example – aggregation

Preferences on decision criteria

Partial order



$$\mu(X_4) \succ \mu(X_1), \mu(X_4) \succ \mu(X_2), \mu(X_1) \succ \mu(X_2), \mu(X_3) \succ \mu(X_2)$$

Interaction index constraints

$$I(X_1, X_2) < 0, I(X_1, X_4) > 0.1 \text{ and } I(X_3, X_4) > 0.1$$

Example – aggregation

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Choquet integral (C.i.)

Farm	Housing	Feeding	Behaviour	Health	C.i.	w.a.m.
A	1.000	1.000	0.750	0.250	0.250 (5)	0.725 (3)
B	0.750	0.750	0.750	0.750	0.750 (1)	0.750 (2)
C	1.000	0.625	0.500	1.000	0.737 (2)	0.825 (1)
D	0.250	0.500	0.750	0.750	0.437 (4)	0.550 (5)
E	0.375	1.000	0.500	0.750	0.478 (3)	0.638 (4)

Shapley value (normalised)

	Housing	Feeding	Behaviour	Health
	0.900	0.100	0.900	2.000

Interaction index

	Feeding	Behaviour	Health
Housing	*-0.211*[1)]	0.062	*0.462*
Feeding		0.100	0.100
Behaviour			*0.362*

[1)]cursiv: constraints

Conclusion

Multicriteria Decision Making using fuzzy measures and integrals supports

- **aggregation by the Choquet integral**
- **importance of criteria (e.g. identifying a hidden decision behaviour, building a decision strategy in terms of importance and interaction)**
- **deal with interacting criteria**

But …

- **the richness of fuzzy integrals has to be paid by the complexity of the model which increases with the number of criteria to be aggregated (Grabisch, 1996)**

Literature

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