A Markov model for optimal feeding and marketing decisions in production units of growing pigs

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Abstract

In the pig production system, feeding is the most important factor that has a direct influence on the quality of the meat and the costs of the production unit. Another important element is the timing of slaughter (the marketing decision) that refers to a sequence of culling decisions until the production unit is emptied. In the production system, the economic optimizations of feeding and marketing decisions are interrelated and there is a need for a simultaneous analysis. In this study a stochastic optimization model is developed at pen level. In the model the state of the system is updated using a Bayesian approach based on on-line data obtained from a set of sensors in the pen. More precisely, two statistical models are used to update estimates of live weight and growth rate on a weekly basis. The proposed models are tested based on the data from a Danish farm to show the model may be used as decision support in finding optimal feeding and marketing decisions.

Introduction

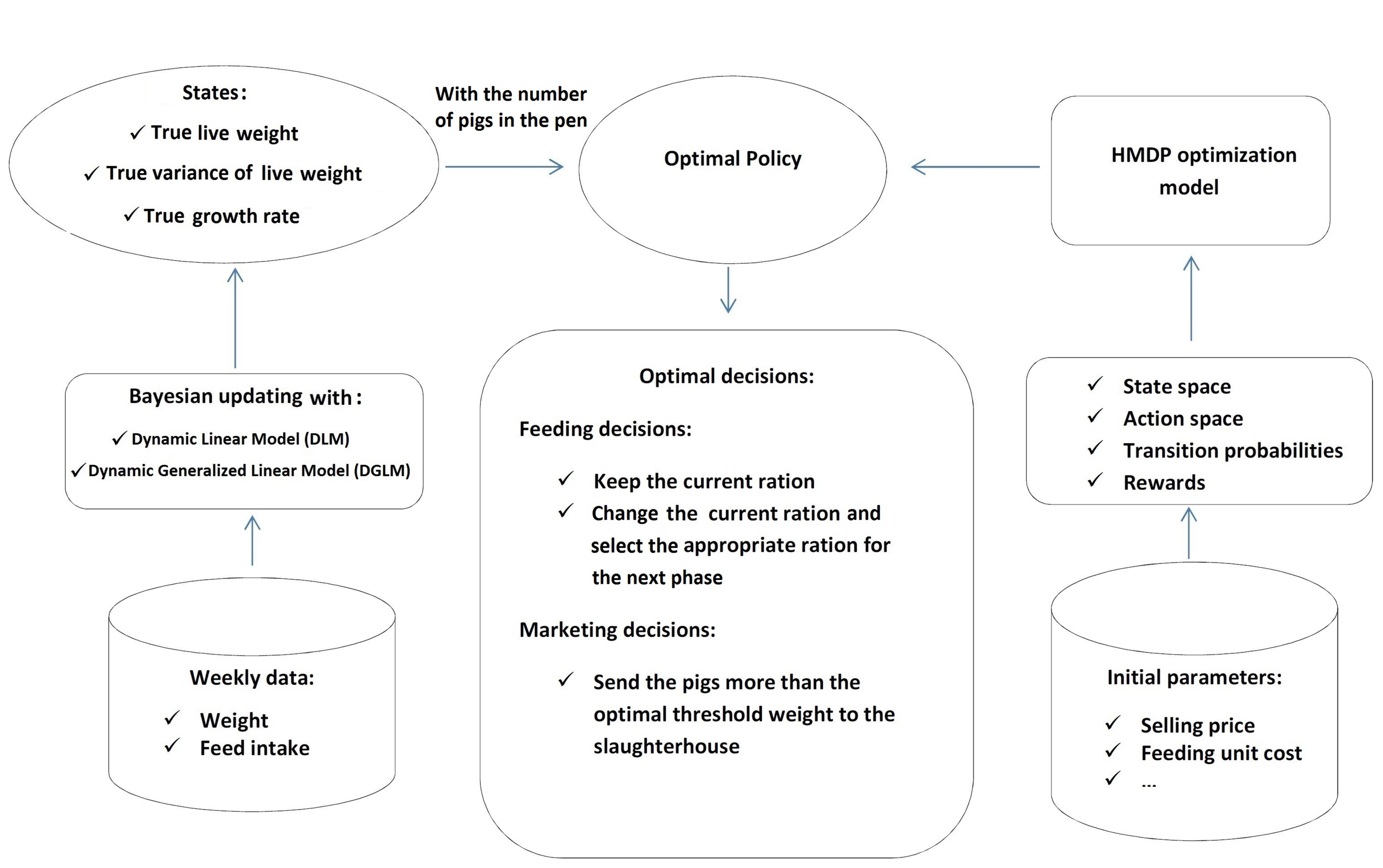
- In the animal production units, the economic optimisation of feeding and marketing decisions is interrelated and hence it requires a simultaneous analysis. As a result, there is a need to develop a sequential decision model which considers both feeding and marketing decisions.
- The feeding and marketing decisions are modelled using a *Hierarchical Markov Decision Process* (HMDP) in three levels. A HMDP is an extension of a traditional *Markov decision process* (MDP) where a series of finite-horizon MDPs are built together into one process at the founder level called the main process.
- The model considers on-line data from a set of sensors in the pen measuring the pig weights and the feed intake. A Bayesian approach is used to update the state of the system such that it contains the relevant information based on the previous measurements. More precisely two *state space models* (SSMs) for Bayesian forecasting are used to update the estimates of live weights and feed intake on a weekly basis.

Main Objectives

1. Combining the feeding and marketing decisions using a sequential optimisation model (three-level HMDP).
2. Estimation of latent parameters in the production unit by the statistical models (SSMs).
3. Embedding the statistical models (SSMs) into the optimization model (HMDP) to increase the precision of feeding and marketing decisions.
4. Developing a real-time decision support framework based on on-line data acquired from a set of sensors in the pen.

Materials and Methods

Decision framework



Dynamic Linear Model (DLM)

Observation equation:
$$\begin{pmatrix} W_{t,f} \\ FE_{t,f} \end{pmatrix} = \begin{pmatrix} 1 & 0 \\ k_{1(t,f)} & k_2 \end{pmatrix} \begin{pmatrix} TW_{t,f} \\ Z_{t,f} \end{pmatrix} + \upsilon \quad (1)$$

System equation:
$$\begin{pmatrix} TW_{t,f} \\ Z_{t,f} \end{pmatrix} = \begin{pmatrix} 1 & 1 \\ 0 & 1 \end{pmatrix} \begin{pmatrix} TW_{t-1,f} \\ Z_{t-1,f} \end{pmatrix} + \omega \quad (2)$$

- $W_{t,f}$: Average live weight at time t
- $FE_{t,f}$: Average feed intake in interval $[t, t+1]$
- $TW_{t,f}$: True live weight at week t
- $Z_{t,f}$: True growth rate at time t
- V : System variances (constant) - estimated by EM algorithm
- W : Observation variances (constant) - estimated by EM algorithm

Dynamic Generalized Linear Model (DGLM)

$$f(s_t^2|\eta_t) = \frac{exp(\frac{-s_t^2(n_t-1)}{2\sigma_t^2})(\frac{n_t-1}{2\sigma_t^2})^{\frac{n_t-1}{2}}(s_t^2)^{\frac{n_t-3}{2}}}{\Gamma(n_t-1)} \quad (3)$$

$$g(\eta_t) = \sigma_t^2 \quad (4)$$

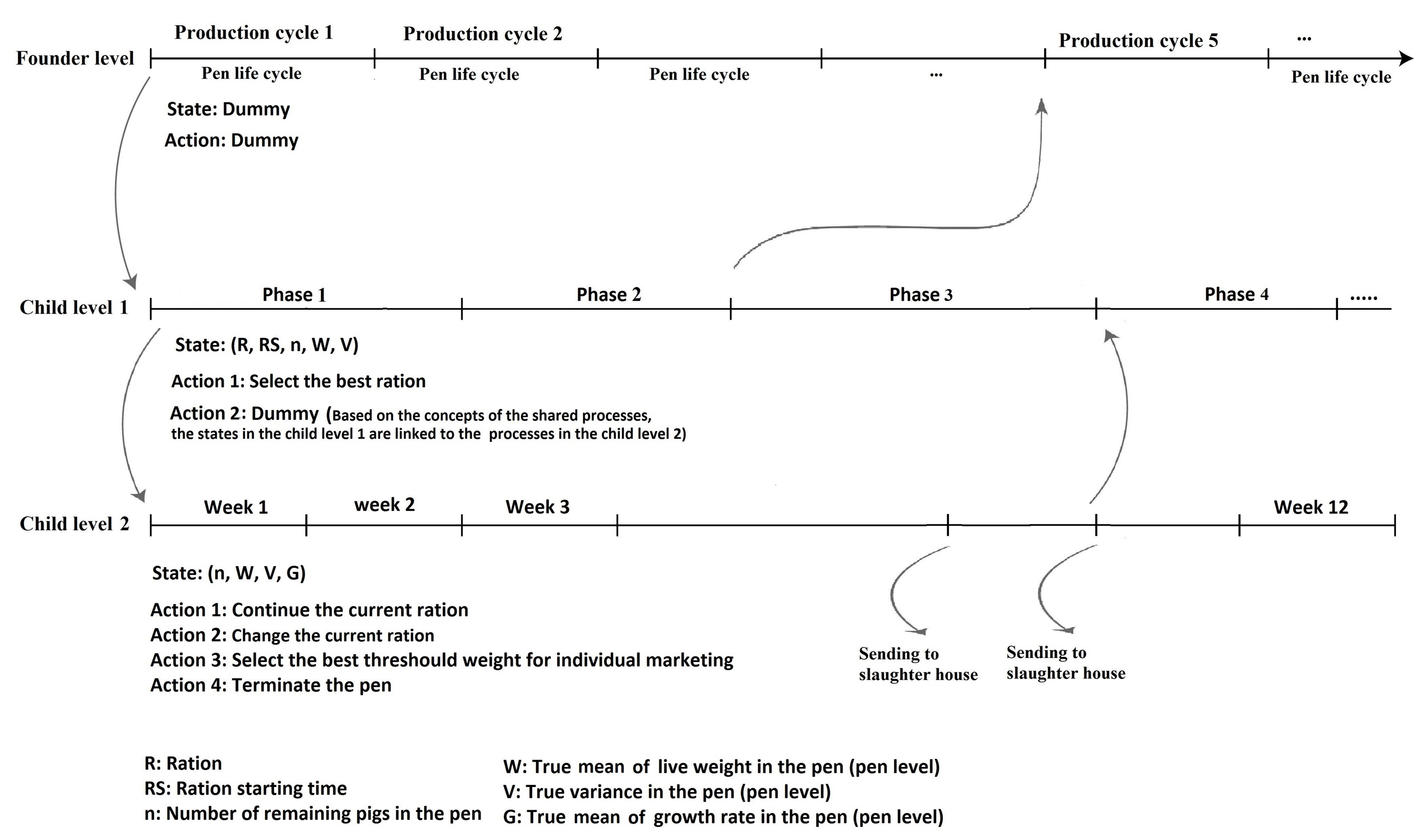
where $g(x) = \frac{1}{x}$

System equations:

$$\sigma_t^2 = G_t \sigma_{t-1}^2 \quad (5)$$

- s_t^2 : Sample variance of the live weights in pen.
- σ_t^2 : True variance of the live weight in the pen.
- $G_t = \frac{t}{(t-1)}$
- n_t : Number of pigs in the sample for s_t^2

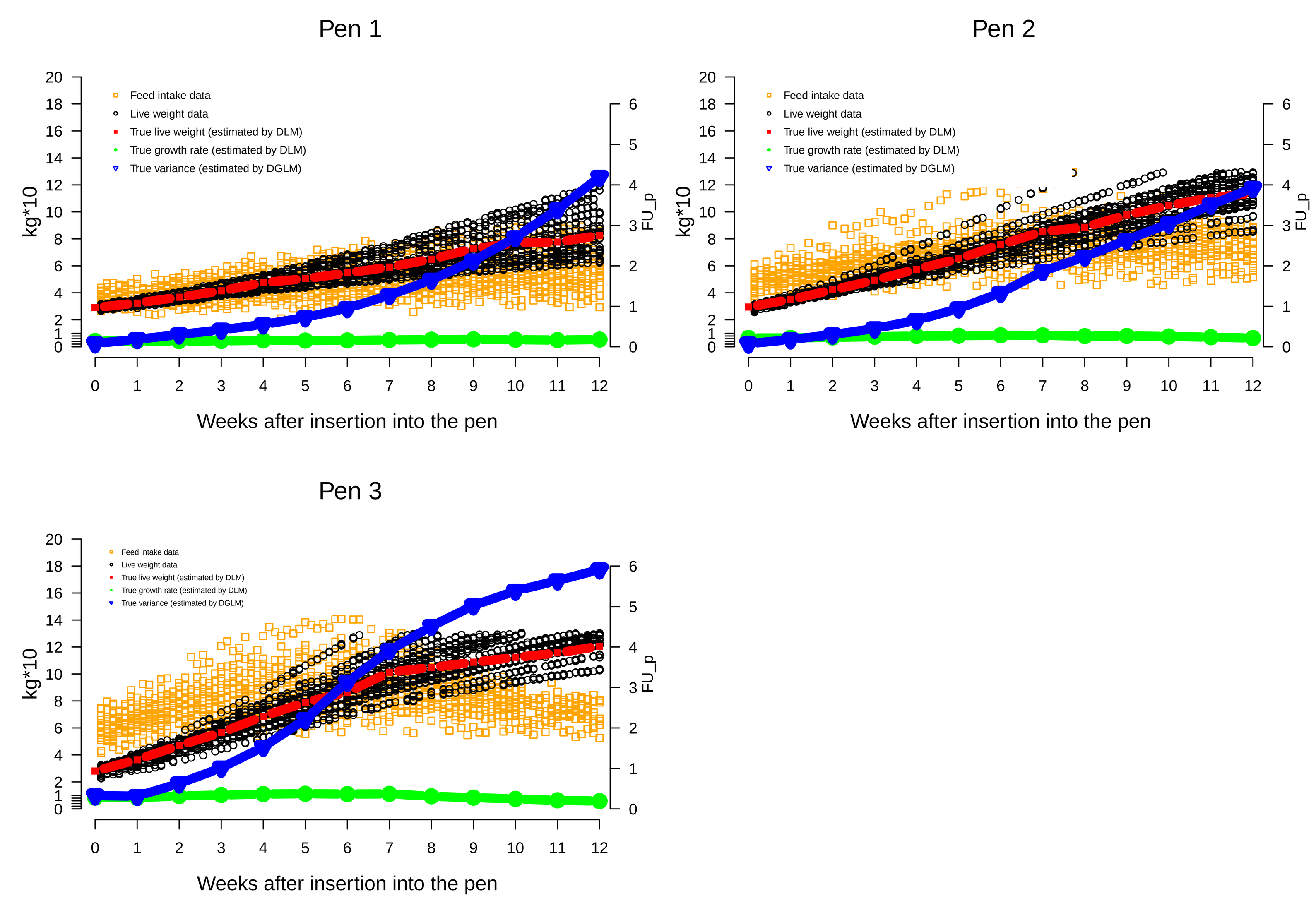
Three-level HMDP



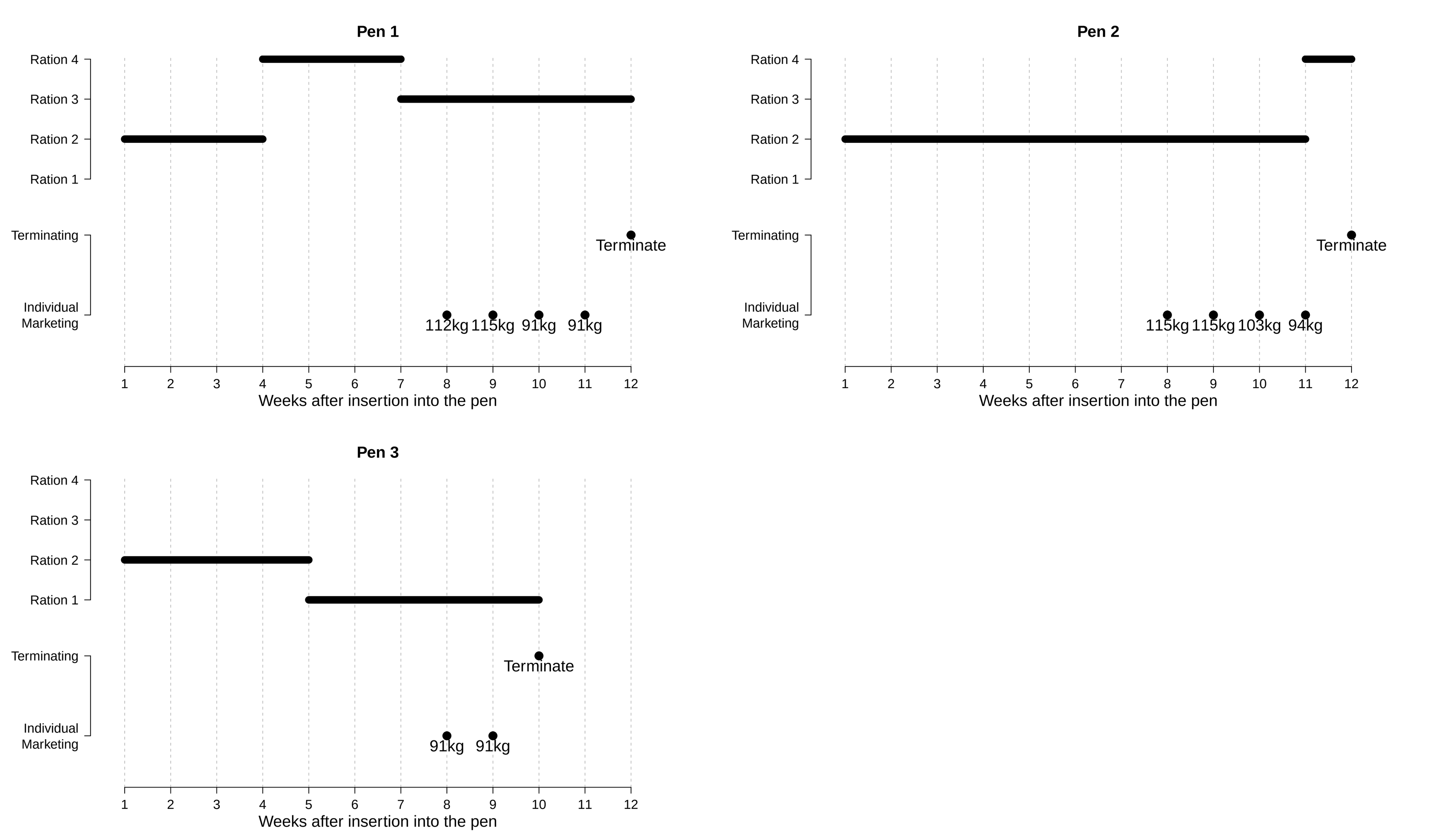
Results

To show the efficiency of the proposed optimisation model, we implemented our model in the three pens with different genetic properties in the growth rate.

Output of statistical models



Output of optimization model



Conclusions

- The three-level HMDP could find the optimal feeding and marketing decisions in the pen level with 18 animals.
- The latent parameters could be estimated precisely and they were used as the state variables in the three-level HMDP.
- Future research will focus on solving the problem in the herd level with at least 300 animals and here an approximation method may be used.

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