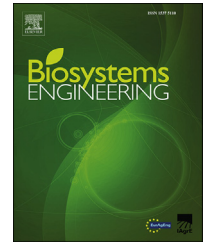


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journal homepage: [www.elsevier.com/locate/issn/15375110](http://www.elsevier.com/locate/issn/15375110)**Special Issue: Engineering Advances in PLF****Research Paper****Feed-forward and generalised regression neural networks in modelling feeding behaviour of pigs in the grow-finish phase<sup>☆,☆☆</sup>**

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Feeding patterns of pigs have been investigated for use in management decisions and identifying sick animals. Development of models to predict feeding behaviour has been limited due to the large number of potential environmental factors involved and complex relationships between them. Artificial neural networks have been proven to be an effective tool for mapping complicated, nonlinear relationships between inputs and outputs. However, they have not been applied to feeding behaviour prediction. In this study, we compared the use of feed-forward (FFNN) and generalised regression neural networks (GRNN) in forecasting feeding behaviour of pigs in the grow-finish phase, using time of day and temperature humidity index as inputs. Models were calibrated on data from 1923 grow-finish pigs collected from 2008 to 2014, and their predictive ability was tested using data from four additional grow-finish groups collected from 2014 to 2016. Results indicated that FFNN trained with the Levenberg–Marquardt (LM) and scaled conjugate gradient (SCG) algorithms were the most accurate forecasting models. In three of the four validation groups, models trained with LM and SCG algorithms exhibited strong performance, with correlations between predicted and observed feeding behaviours ranging from 0.623 to 0.754. Large deviations between predicted and observed behaviours in the fourth validation group were probably the result of an outbreak of pneumonia, which demonstrates the potential for the model to be used in automated detection of disease outbreak and other stress events. This work is the first step in developing a fully automated system for detecting changes in feeding behaviour.

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**Table of nomenclature and abbreviations**

$\alpha_k$	Step size in neural network training process	$\mathbf{o}$	Vector of observed feeder visits
ANN	Artificial neural network	$\mathbf{p}$	Vector of predicted feeder visits
$\beta_k$	Conjugate gradient update parameter	$P(w_k)$	Penalty term in the Bayesian regularisation training algorithm
BR	Bayesian regularisation algorithm	$p_i$	Measure of the distance between the input and the stored pattern in the $i$ th pattern layer of a generalised regression neural network
$d_k$	Search direction in neural network training process	popsize	Population size in the fruit fly optimisation algorithm
Dist <sub><math>i</math></sub>	Distance between the $i$ th fruit fly position and the origin	$r$	Pearson correlation coefficient
$\mathbf{e}$	Residual error vector	$R^2$	Coefficient of determination
$\nabla E(w_k)$	Gradient of the error function	RH(%)	Percent relative humidity
FFNN	Feed-forward neural network	$r_k$	Negative gradient of the error function
FFNN-BR	Feed-forward neural network trained with Bayesian regularisation algorithm	RMSE	Root mean square error
FFNN-LM	Feed-forward neural network trained with Levenberg–Marquardt algorithm	SCG	Scaled conjugate gradient algorithm
FFNN-SCG	Feed-forward neural network trained with scaled conjugate gradient algorithm	$S_i$	Parameter being tested in fruit fly optimisation algorithm
FOA	Fruit fly optimisation algorithm	$\sigma$	Smoothing parameter (spread)
$\gamma_k, \rho_k$	Regularization parameters in Bayesian regularisation training algorithm	$S_s$	Simple summation of pattern layer outputs in a generalised regression neural network
GRNN	Generalised regression neural network	$S_w$	Weighted summation of pattern layer outputs in a regression neural network
$I$	Identity matrix	$\mathbf{t}$	Vector of observed outputs
$J$	Jacobian matrix of output errors	$T(^{\circ}\text{C})$	Outside temperature in degrees Celsius
$k$	Iteration count in the neural network training process	THI	Temperature humidity index
LM	Levenberg–Marquardt algorithm	$\mathbf{w}$	Vector of connection weights in a neural network
LMS	Least-mean-square algorithm	$\mathbf{a}$	Input to a generalised regression neural network
maxgen	Number of iterations in fruit fly optimisation algorithm	$\mathbf{a}^i$	Pattern vector for neuron $i$ in a generalised regression neural network
$\mu$	Scalar that controls the learning process in the Levenberg–Marquardt training algorithm	X_axis, Y_axis	Initial fruit fly swarm location in fruit fly optimisation algorithm
$N$	Number of input–output pairs in the training data set	$\mathbf{y}$	Vector of predicted outputs

**1. Introduction**

Feeding behaviour of grow-finish pigs can be used to inform producers of both health status and stress level. Many parameters have been studied to better understand feeding behaviour of pigs, including feed intake, meal length, meal interval, number of meals, and total time spent eating (Morgan, Emmans, Tolkamp, & Kyriazakis, 2000; Nienaber, McDonald, Hahn, & Chen, 1990; Nienaber, McDonald, Hahn, & Chen, 1991; Quiniou, Dubois, & Noblet, 2000). Most of these measurements have been obtained from feeding systems that allow only one pig to feed at any given time, which is not representative of commercial production where pigs typically feed in a group setting (Brown-Brandl, Rohrer, & Eigenberg, 2013).

Feeding behaviour is dependent on several environmental and genetic factors, including but not limited to temperature, humidity, gender, breed, and time of day. Deviations from normal feeding behaviour may indicate that grow-finish pigs are experiencing a stressful event, such as illness, issues with feed quality, or heat-related stress. Models of feeding

behaviour could be used as a management tool to assess stress levels within a population and to identify sick animals.

Several different approaches have been used to analyse and model feeding behaviour of pigs. Linear regression and analysis of variance models have been used extensively (Brown-Brandl et al., 2013; Nienaber et al., 1990, 1991; Quiniou, Noblet, van Milgen, & Dubois, 2001). However, application of these methods is limited due to complex, non-linear relationships between multiple input variables (Comrie, 1997). Gaussian models (Morgan et al., 2000), three-process random models (Berdoy, 1993), and logistic models (Tolkamp & Kyriazakis, 1999) have also been applied to predict feeding behaviour. There are two major drawbacks to these types of models. They tend to be very complex, and they require prior knowledge of relationships between input variables, i.e. a predefined functional form for the model.

Artificial neural networks (ANN) have emerged as a powerful tool in applications where complexity of relationships between inputs and outputs makes formulating a comprehensive mathematical model nearly impossible (Hecht-Nielsen, 1989). An ANN is a set of computing systems that imitates learning abilities of neurons in the brain.

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