Agronomy Research **18**(S2), 1300–1306, 2020
https://doi.org/10.15159/AR.20.029

Usability improvements of the Thermipig model for precision pig farming

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Abstract. Pig livestock farming systems encounter several economic and environmental challenges, connected with meat price decrease, sanitary norms, emissions etc. To deal with these issues, methods and models to assess the performance of a pig production system have been developed. For instance, Thermipig model represents the pig fattening room and simulates performances of pigs at the batch level, taking into account interactions between the individual variability of pigs, farmer's practices, room characteristics and outdoor climate conditions. The model requires some static basic inputs fulfilled in several spreadsheets (such as rooms, pigs, and dietary characteristics) but also data files for voluminous variable inputs (such as outdoor temperature or climate control box parameters) for further modelling and outcome producing. This leads to challenges in data providing by the farmers and have to be improved. This paper deals with the implementation of the separate modules of the developed data warehouse system for usability improvements of the Thermipig model. The idea is to substitute input from the data files with online data input and automated variable processing by the model using the python script for connection to the remote data warehouse. The data warehouse system is extended with 'Property Sets' section dealing with all the operations that can be performed to a set of input variables. This approach demonstrates the ability of the data warehouse to act as data supplier for the remote model. As well the outcome of the model is also transferable back to the data warehouse for evaluation. This work is done within the Era-Net SuSan PigSys project - Improving pig system performance through a whole system approach.

Key words: precision agriculture, precision livestock farming, modeling, Thermipig model, system usability, system integration.

INTRODUCTION

European pig production still continues to encounter economic and environmental challenges. Currently the maximum efficiency and productivity of an animal farm can be achieved by applying Precision Livestock Farming (PLF) (Porto et al., 2012; Pierpaoli et al., 2013). PLF aims to improve efficiency of production together with improving animal welfare (Banhazi et al., 2012).

Pig farms can be found everywhere in Europe (Marquer et al., 2014), but in each country different types of building and management rules can be applied. As well climatic conditions vary from country to country. All these factors influence the performance and welfare of the pigs and more generally the multiple performances of the pig fattening unit (Cecchin et al., 2019; Machado Filho, 2000). Profitability in commercial pork production is determined not only by daily gain and backfat thickness, but also by lean growth rates and levels of feed intake and feed conversion ratio (Paura & Jonkus, 2016). Accurate definition of the wide panel of local situations requires collection of precise information on climate, barn characteristics, indoor management rules, type of pigs and feeding strategies. Afterwards a modelling approach can be used to simulate and predict pig growth and behaviour as well as the behaviour of the fattening unit system through a representation of interactions among its components. Several models are available to simulate the growth performance of pigs, so-called 'Growth model', in different feeding or management conditions either at the average individual level (van Milgen et al., 2008; Niemi et al., 2010; NRC, 2012) or at the batch level (Cadéro et al., 2018). However, none of them deals with the interaction with ambient conditions. Therefore the growth model proposed by Cadéro et al. (2018) was merged to a bioclimatic model (Marcon et al., 2016), thus creating a new model called Thermipig (Brossard et al., 2019). Thermipig model is used in the present paper as a reference for possible usability and functionality improvements dedicated to further implementation of decision support systems for PLF purpose.

The aim of the development of the Thermipig model is to propose a tool that can help to identify target climate control box parameters of the fattening barn as well as insulation type, equipment installation or practices for improved sustainability of pig production under different climatic conditions. First simulations have been performed with a computer version of the model to evaluate the impact of theoretical technical options or indoor management rules on pigs' performance and energy use under different outdoor conditions.

The next step of the development of Thermipig model is to increase its usability through a user-friendly Web interface, integrated into a whole data warehouse system. This work is part of the Era-Net SuSan PigSys project (Improving pig system performance through a whole system approach).

DATA WAREHOUSE CONCEPT

Data warehouse (DW) is considered as a cloud-based data storage and processing unit, with capabilities to combine unlimited data sources like other existing systems and available on-farm generated data. The developed DW follows best practices in distributed and asynchronous data processing by utilizing multi-agent techniques in conjunction with real-time data warehousing approach (Komasilovs et al., 2019).

The DW architecture consists of various main components to ensure that information is stored for further analysis. After the data has been entered into the DW, the next step has to be the data analysis and decision making for getting added value from the data. Several potential models can be integrated into the DW to conclude on different aspects of pig status and variation of indoor conditions. Pig status models can include growth model and overall pig health model. Pig behaviour models can include criteria such as pig laying and standing behaviour model, aggressiveness and feeding behaviour. Description of indoor conditions is mainly based on a barn microclimate model. The DW idea and concept allow to integrate models based on the data collected within the DW or provide an API for other external system to get the data from the warehouse and then store the model output back to the warehouse. Within this work DW is extended with module for data input for external model called Thermipig.

GENERAL STRUCTURE OF THERMIPIG MODEL

The Thermipig model is of a multi-object type, mechanistic, dynamic, determinist and pig centred. The bioclimatic part of Thermipig is used to model the thermal exchanges at the room level. It represents and predicts the energy balance and direct energy consumption at the room level, and allows to calculate the ventilation rate and the input of heat required to achieve the expected ambient temperature. Therefore, it accounts for the interaction between the characteristics of the building in terms of room characteristics (size, insulation), equipment (fans, heater), parameters of the climate control box and characteristics of the group of pigs (number, weight, performance, heat production). The growth model part of Thermipig is an individual-based model adapted from the InraPorc model (van Milgen et al., 2008), combined with a generator of the within-room pig population and additional tools dealing with management issues such as mortality rate or delivery to slaughterhouse. It allows to calculate daily individual performance (weight, feed consumption) and heat production that are used as inputs by the bioclimatic model. Thermipig model allows for a good prediction of performance and ambient temperature (Brossard et al., 2019).

The model is written in Python language and several additional Python modules and Excel files are used to run the overall model. General structure of the Thermipig model execution is presented in Fig. 1.

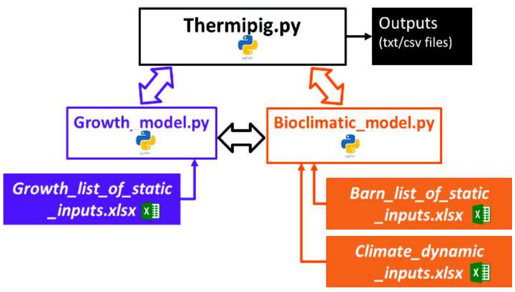

Figure 1. General structure of Thermipig model execution.

One of the main requirements for the model execution is inputting extensive amount of static and dynamic variables in the growth and bioclimatic modules. When the process is implemented locally on a computer, Excel files with multiple sheets are used to upload variable inputs and generate results. Growth model static inputs are related to management practices at the farm and includes information about shipment decisions, feeding strategy, batch management, room characteristics, animal characteristics and variability. The bioclimatic model static inputs are related to climate control parameters and include data describing the equipment available (fan system, heating system…), room dimensions and insulation. The bioclimatic dynamic inputs include hourly data on outdoor temperature and humidity, and dynamic changes in fan and heating system regulation setpoints (if automatically recorded by the equipment).

There are many disadvantages of using the Excel files for variable input. Firstly, the user is required to have the corresponding software, which is not free. Secondly, it is fastidious to input a lot of information when all the fields are difficult to observe simultaneously. In addition, the Excel files can be accidentally lost or deleted when they are stored on a local computer. Another challenge is to maintain and organise all the files in order to store and process the data describing multiple and different samples.

The aim of this paper is to present a developed user interface for substituting Excel data input with a user-friendly Web interface, which is integrated into the whole DW system to increase the model usability. In software engineering, usability is the degree to which a software can be used by specified consumers to achieve quantified objectives with effectiveness, efficiency, and satisfaction in a quantified context of use. There are cases when systems have adequate functionality, but without an appropriate usability the users will not be able to exploit it efficiently and will not adopt it. Furthermore, the output of Thermipig model is also changed from the file output to a web output directly.

USER INTERFACE FOR DATA INPUT

User interface for Thermipig model inputs is created as a part of the DW and is integrated in it. Technologies used for web interface development are Angular and Bootstrap (front-end) and Java 8, Spring Boot and MongoDB (back-end).

Developed DW platform is accessible online: https://pigsys.science.itf.llu.lv/. Any interested person can log in and test it.

The DW system is extended with 'Property Sets' section dealing with all the operations which can be performed to a set of input variables. Each system user can define multiple property sets, copy and delete them, edit the drafts and see the results of the modelling performed upon property set (the ones that have been processed by the Thermipig model). Available operations for each property set are demonstrated on Fig. 2.

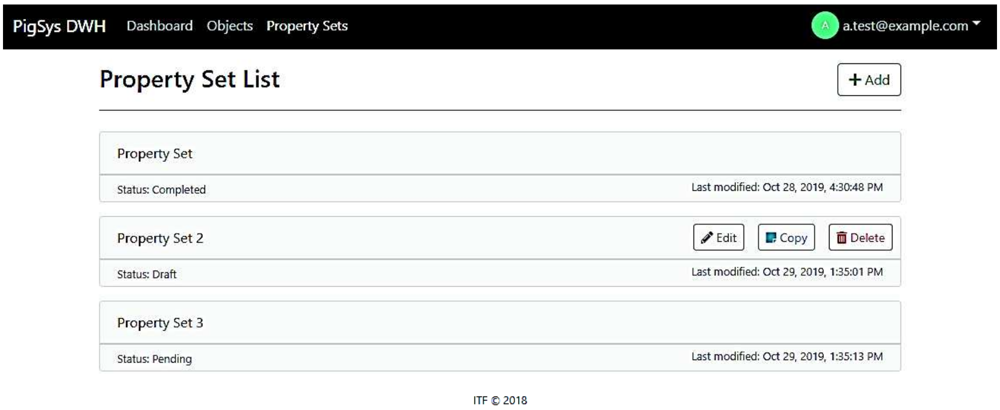

Figure 2. 'Property Set' section in PigSys DWH for data input.

When creating a new property set the only required field is the name of the set. All variable inputs are divided into groups to ease the process of filling the data and make it more organized. It is possible to either add properties one by one manually or add predefined sets of static properties and their default values automatically. In order to make the input process as easy as possible, inputs that can only have predefined values are represented by list boxes (Fig. 3).

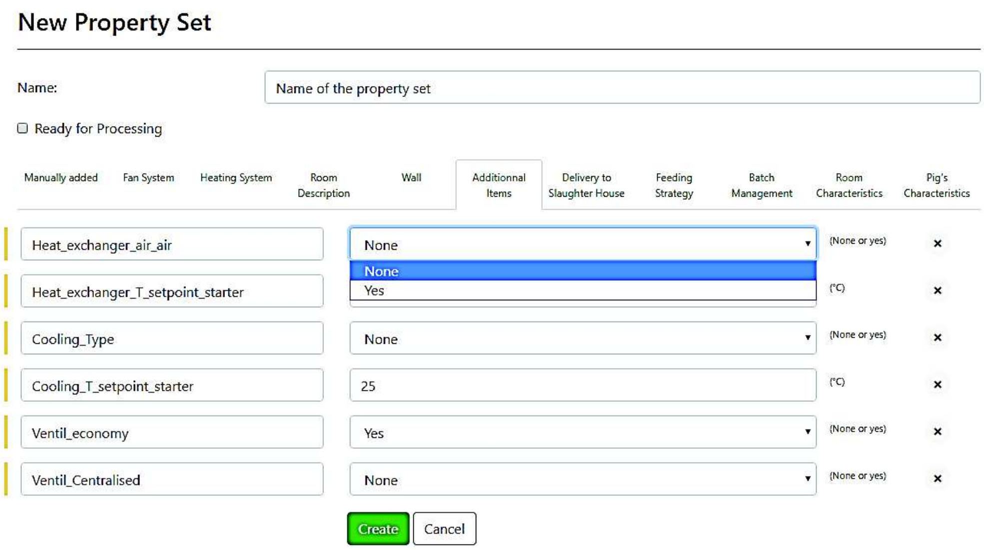

Figure 3. Creating a new property set.

A property set can be edited as long as it is a draft. To make the property set available for the Thermipig model to process, the user must check 'Ready for processing' changing status from 'Draft' to 'Pending'. Once the property set is saved with the status 'Pending' it becomes read-only and is processed by the model during next computation session. For usability purposes, when users want to define some other practices, such as the feeding strategy, the type of pig and/or regulation rules in a given room, a copying function for all property sets, including pending and completed, is available.

For Thermipig model calculations, a dataset of hourly climatic conditions (mainly outdoor temperature) is needed. Climatic data has been collected for several geographical locations in France, Sweden, Denmark, and Latvia and is embedded into the model. In the future users will be able to define the target location for the simulation and an appropriate historical dataset will be used.

PYTHON SCRIPT FOR CONNECTION TO THE DATA WAREHOUSE

Thermipig model was initially developed using Excel files for input variables. Then Python script used the Excel file, processed it by the rows and columns and assigned local Python variables to values defined in each specific cell in the Excel file. In this case, it was needed to use an additional library to ease the processing of the Excel files, like xlrd library. In the modified procedure Thermipig model will directly get the input values from the remote DW. Below is an example of the Python script snippets for connection to the remote DW and property set fetching. This procedure can be performed on-demand or scheduled according to user needs and computation power available for modelling. It consists of following logical steps:

- authentication of machine-to-machine application (the script) and token acquisition

```
headers = {'content-type': "application/json"}
payload = {
    "client_id": "...",
    "client_secret": "...",
    "audience": "pigsys-web-api",
    "grant_type": "client_credentials"
}
auth = requests.post('https://pigsys.eu.auth0.com/oauth/token',
                     json=payload, headers=headers).json()

headers = {
    'content-type': 'application/json',
    'Authorization': auth['token_type'] + ' ' + auth['access_token']
}
```

- requesting the system wide list of property sets available for processing

```
propertySetIds = requests.get(API_HOST + '/api/properties/processing',
                              headers=headers).json()
```

- in loop fetching parameters for a given property set

```
for id in propertySetIds:
    propertyData = requests.get(API_HOST + '/api/properties/processing/' + id,
                                headers=headers).json()
```

- processing the parameters through Thermipig model and sending results back to DW

```
requests.post(API_HOST + '/api/properties/processing',
              json={"id": id, "status": "In progress"},
              headers=headers)

# model
result = model(propertyData)
# end of model

requests.post(API_HOST + '/api/properties/processing',
              json={"id": id, "status": "Completed", "result": result},
              headers=headers)
```

After the Thermipig model has performed calculations and simulations, its outputs are transferred directly to the remote DW and are available in the user interface.

There are different outputs from the Thermipig model. One output set is related to the individual pig's performance including age, body weight, average daily gain, feed intake, protein and lipid content and deposition and mineral (N, P) retention and excretion. The other set is related to room ambient conditions including hourly temperature, ventilation and heating rates and energy consumption, hourly relative humidity and CO_2.

DISCUSSION AND CONCLUSIONS

This article is focused onto the demonstration of the approach applied to develop the data interface for an existing model and to integrate it into the previously developed DW platform.

Developed DW is an universal system as it allows connectivity to different multiple external systems, each of which can produce different data aimed for various livestock of PLF branches.

Proposed approach demonstrates the ability of joining geographically distributed solution, as presently the DW system and external Thermipig model are located in different institutess. Thermipig model itself is processed in France, but input variables and outputs are stored in the DW, deployed in Latvia. Especially for projects / applications developed in partnership, the geographically distributed solution allows to join external systems that can have their own particular development within each partner, provided that the links between modules are kept coherent. It allows also to join systems without ownership issues, each module being potentially hosted by its owner.

Implemented web interface for variable input eases the process of preparation for Thermipig calculations and therefore increases the usability of the model. In the future, it is planned to get feedbacks from the farmers concerning their evaluation of the proposed interface and of the approach for variable inputting process to the model.

ACKNOWLEDGMENTS. Scientific research, publication and presentation are supported by the ERA-Net SusAn Project 'Improving pig system performance through a whole system approach (PigSys - 2817ERA08D)' funded by the Latvian State Education Development Agency, subordinated to the Ministry of Education and Science and by the French ANR (grant n°ANR-16-SUSN-0003-02).

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