Chapter 22

Static/Dynamic Zoometry Concept to Design Cattle Facilities Using Back Propagation Neural Network (BPNN)

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Additional information is available at the end of the chapter

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Abstract

The dairy cattle productivity is largely dependent on the facility quality and environmental condition. Various researchers had conducted a study in this field, but it is not developing the knowledge of animal dimensions and behaviors correlated with their facility design. Complexities of dynamics zoometry depend on cow behaviors that they are forced to use neural network (NN) approach. Hence, the purpose of this chapter is to create the concept of static and dynamic zoometry to guide the ergonomics facilities design. The research started with study literature on anthropometry, dairy cattle, facility design, and neural network. The following step is collecting the static zoometry data in 16 dimensions and dynamics zoometry in 7 dimensions. On the one hand, static data is utilized as an input factor. On the other hand, dynamic data is utilized as desire factor of back propagation neural network (BPNN) model. The result of BPNN training is utilized to design the dairy cattle facilities, e.g., cage with minimal length = 357.67 cm, width = 132.03 cm (per tail), and height = 205.28 cm. The chapter successfully developed the concept of zoometry approach and BPNN model as a pioneer of implementing comfort knowledge.

Keywords: animal comfort, cattle cage, facility design, neural network, zoometry, ergonomics, milk productivity

1. Introduction

Milk is an important food commodity in the world as it provides calcium, phosphorous, magnesium, and protein which are all essential for human health. Adequate consumption of milk from early childhood and throughout life strengthens bones and protects against diseases. Consuming dairy product, especially milk, can increase children bone health and development, develop a positive brain concentrations of glutathione (GSH), and increase the body's resistance against many infectious diseases and diseases caused by malnutrition and reduce cancer risk [1–4]. Milk can directly be consumed or manufactured into other dairy products such as cheese, ice cream, butter, ghee, cream, yogurt, etc. Milk provides the following beneficial nutrients in varying quantities [5–8]:

1. Calcium—for healthy bones and teeth
2. Phosphorous—for energy release
3. Magnesium—for muscle function
4. Protein—for growth and repair
5. Vitamin B12—for production of healthy cells
6. Vitamin A—for good eyesight and immune function
7. Zinc—for immune function
8. Riboflavin—for healthy skin
9. Folate—for production of healthy cells
10. Vitamin C—for the formation of healthy connective tissues
11. Iodine—for regulation of the body's rate of metabolism (how quickly the body burns energy and the rate of growth

As community realizes the importance of milk product in their life, it boosted the demand for milk production. As consequence, the number of dairy cattle farmers and productivity should be increased. The government needs an approach to increase fresh milk production. One of the methods to increase the milk productivity is maintaining cow facilities and developing them to be more comfortable for the cattle (cage, free stall, floor, etc.). Several researchers investigated the dairy cattle comfort including cow house and respective facilities. Cook et al. reported that physical accommodation of dairy cattle should provide a relatively dry area for the dairy cattle to lie down and be comfortable [9]. Dairy cow overcrowds could reduce rest time, increase idle standing in alleys, alter feeding behavior, and, in general, reduce cow comfort [10]. A study conducted on 47 farms in Northeastern Spain explained the significant effect of a stall on the productivity of dairy cow and impact on milk production and cow health [11]. The cow facilities should be constructed to minimize time to reach food and water. Free stall facility is usually selected to minimize the effect of weather changes and improve cleanliness and cow comfort. Dairy facilities should be designed to keep the cows and calves comfortable in order to maintain dry matter intake (DMI) and thus maximize economic production. Other studies have reported similar results. Based on Jim Reynolds research, the cattle comfort can be identified into five factors for heat stress, sanitation, free stall design, walking surface, and

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walking distance [12]. In short, dairy cattle facilities are an important factor of key success in milk business, and it should be designed to keep the cow and calves comfortable in order to maintain milk quality and thus maximize economic production.

In order to provide a solution to comfort design for dairy cow facilities, the physical ergonomics knowledge is needed. The important knowledge of physical ergonomics area for a human body is defined as anthropometry. It studies the variation of the human body dimensions in static and dynamics condition [13]. Using the same analogy, this study converts the concept of anthropometry into the concept of zoometry to study the impact of variation of animal body dimensions. This analogy imagines that animal (cow) requires comfort in order to gain optimal milk production, similar to human. A human requires comfort at work in order to reach high productivity. Zoometry is derived from Greek ζώο (zǿo) which means animal and μέτρον (metrí̲ste) that means a measurement. Zoometry concept is defined as static and dynamics animal measurement dimension in order to determine the physical variation of the specific animal population. This research utilized dairy cattle zoometry concept to design cattle facility (house, free stall, floor, etc.) in order to increase the dairy cattle comfort and milk production. This study considers static and dynamic measurement because it constitutes cattle main activity. There are three main activities that are affected by the static and dynamic condition such as feeding, lying, and standing or transition events between lying and standing. Zoometry concept can deter cattle from annoyances or uncomfortable facility. The research promotes pioneer strategy to improve the cow comfort using zoometry concept.

Directly and manually measuring dairy cattle dimensions based on zoometry concept is time-consuming and costly. Analysis data of dairy cattle dimensions can be employed to eliminate the problems. Unfortunately, relationship complexity of each dimension on dairy cattle is hard to describe in mathematics formula or in the regression model. Artificial intelligence back propagation neural network (BPNN) I was used in determining the best solution. It can eliminate some cost and improve efficiency. The BPNN model can be utilized to predict pattern making-related body dimensions by inputting few key dairy cattle body dimensions.

2. Zoometry concept

2.1. Anthropometry

The first step to understand the zoometry concept is knowing the anthropometry concept. Cattle zoometry concept is adapting the principles of anthropometry rules for human dimensions. Anthropometry is human body measurement method in a population and analyzes that measurement for various purposes. This measurement could be utilized in architecture, product design, clothing design, child nutrients, design workplace, etc. The ISO 7250-1: 2008 intended to explain as a guide for an engineer who is required to determine the size of human physic for their job [14]. The knowledge on human body, technical measurement, and statistic are very important to obtain a higher quality of anthropometry implementation. Anthropometry will improve work facilities capable to facilitate a person in working physically through ease of reach and access and through the process of cognition of a job [15, 16].

The anthropometry will set up an economical design work facility which means from a marketing point of view, these facilities could be built cheaply. On the other hand, although the design is made with cheaply but can support the performance of human according to the technical needs. Some considerations that can be utilized in anthropometry include data utilized to indicate the characteristics of the target population with limitations contained in the field conditions. The criteria utilized for the design are appropriate for user facilities. The data collected are expected to represent broad conditions that can be utilized for a wider population [17]. The posture utilized by every individual work will be influenced by the body and tool dimension as well as facilities used. The level of relationship between work facility and posture is influenced by the characteristics and frequency of interaction between the two. Generally, anthropometry is divided in into two branches: static anthropometry and dynamic anthropometry [18, 19]. The static anthropometry deals with the measurement process when the human body is in a stable position or in a static condition. On the other hand, dynamic anthropometry deals with measurement process that relates to the measurement of range of human body movement, for example, of arm movement, walking position, and head movement to reach an object.

2.2. Cattle psychology and physiology

Similar to humans, cows are also able to perform a process of cognitive response to the symptoms of the surrounding environment. Cows perform various activities inside an environment which is described in **Table 1** [20].

Dairy cattle cognitive process is exhibited in performing activities by responding to surrounding environment, which is described as follows [21]:

1. ability to distinguish objects around;
2. have a certain emotional level that can be formed because of the interaction with the surrounding environment;
3. ability to show an emotional reaction which is a reflection of the process of cognition;
4. have a different personality from one to another; and
5. ability to conduct social learning.

No	Activities	Daily allocation (hour)
1	Eating	2–5
2	Lying	12–14
3	Interaction	2–3
4	Ruminating	7–10
5	Drinking	0.5
6	Outside pen	2.5–3.5

Table 1. Cow activity.

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Dairy cattle psychology respects to some conditions, e.g., conditions of the cage, SUI as the comfort index, cow's desire to always be in a lying position, cattle density in the room, comfortable and clean sitting position, high-quality feed and drinks, minimum competition to obtain food and drink, cow gets enough room to conduct activity, anti-slip floor, comfortable air cycle, comfortable lighting, and a shady spot [22, 23].

Dairy cattle behaviors are well developed in feeding, environment/microclimate condition, facility design, house, and social communication. The dairy cattle are able to distinguish red, yellow, green, and blue colors. However capability in differentiating between green and blue is poor [24]. Moreover, cattle are able to distinguish simple shapes such as triangles, circles, and line. Color information is important in cow facility design to increase dairy cattle comfort. In the free area, the cow automatically moves from the dark to light area. They tend to avoid strong contrast between sun and shadow. Comparing to human hearing capability, cow possesses almost similar frequency range and are able to listen to high tones that human cannot hear. Cattle hearing is important in inter- and intra-species communication [25]. Cattle sense of touch is important in determining which herbage is rejected or accepted. The secondary/special olfactory system can detect pheromones, volatile chemicals that are important in reproduction and feed selection [26].

Cattle communicate by sending out a different signal such as poses, sound, and smells [24]. A high density of cattle inside the house limits the freedom movement and can increase social stress. Cattle possess a distinct circadian rhythm, in which the main rest, feed, and rumination activities vary according to a fixed pattern. Grazing occupies a large amount of time for dairy cows about 8 hours/day. Grazing behavior is affected by many factors, including environmental conditions and plant species. In a dairy herd of Friesian cows, it was found that there was a consistent order for lying down and standing up [27]. The natural lying down behavior begins when the animal sniffs at the ground while it slowly moves forward. The head and body of the fully developed cow are thrust 0.60–0.70 m forward during the lying down process. When a cow wants to get up in a natural way, it firstly rises to its knees, and afterward the hind part of its body is swung up via the knees, which function as a rocking point.

There are many kinds of dairy cattle, e.g., fries Holland (the Netherlands), Shorthorn (UK), Holstein Friesian (the Netherlands), Jersey (the UK, France), Brown Swiss (Switzerland), Red Danish (Denmark), Drought Master (Australia), etc. The dairy cattle in Indonesia is dominated by Holstein Friesian possessing white and black spot or red spot. The female cow has average weight = 560 Kg to 725 Kg, and the male cow has average weight = 820 Kg to 1000 Kg. The dairy cattle have to grow up from calf, adult cow, mature cow, and old cow. A new-born calf weighs from 90 to 100 pound and has height from 32 to 36 inches. The 6-month-old heifer starts to graze (eat grass) in the pasture. Heifer usually has weight about 400 pounds with height from 38 to 42 inch. Yearling cow has to weight about 700 pounds and height from 47 to 52 inch and still has quite a bit of growing to do before it joins milking herd in another year. Two-year-old dairy cattle start to produce milk and keep on growing for next few years to be a mature cow. It weighs 1200 pound and has height from 53.5 to 55 inch. The last stage is mature cow which has more than 1500 pound and produces optimal milk. Holstein Friesian can produce milk around 57.000 Kg per year with low fat content at approximately 3.5 to 3.7% [28].

Cow body dimension will influence the horizontal movement of the cow when it gets up or lies down. It uses space around 3 m. The moving forward motion is 0.6 m, and minimum distance to the bedding from the head or neck of the cow is approximately 0.2 m [24]. The reach of dairy cattle during feed intake depends on the type of tether and feed alley height. The body length of the cow, from the shoulder area to the tail head and spine, is not flexible which make it difficult for the cow to make sharp changes of direction while it is walking. Therefore much space is required when a cow turns. The range of vision of cattle covers 330–360^0, and the field of vision covered by both eyes at the same time is 25–30^0.

Similar to a human dimension, there are several things that can affect dairy cattle dimension as defined in measurements as follows:

- *Species*

Any different taxonomic levels will have a tendency of different dimensions. The higher differences level of the taxonomy will have higher different dimensions as well. Zoometry measurement should be taken in the similar to animal species (types).

- *Phase development*

Animals that undergo metamorphosis or change in phase of development will have different dimensions in every phase of its path.

- *Age*

Animal body size will vary in each period of growth.

- *Gender*

Male generally has larger body dimensions than females.

- *Clumps*

Diversity clumps in the animals lead to a tendency of difference in size in any dimension zoometry.

2.3. Zoometry concept

Similar to anthropometry for human body dimensions, the zoometry concept concerned with the comparative measurement of the animal body and its part as well as the variables which impact these measurements. The main goal of zoometry is to increase the cattle comfortability which can influence physiological and psychological condition. The good physiological and psychological conditions will increase the amount of daily milk production. Zoometry can be utilized to define the best size of cattle facilities, such as cage size, stall, floor, etc.

The first step to create the zoometry concept is developing a database of cattle dimensions. The zoometry data of dairy cattle are collected from dairy farmers in Indonesia with an average age between 3.5 to 6 years old (optimal daily milk production). Total dairy cattle taken as the sample was around 500 samples. Generally, the measurement is divided into two sections for static dimension (mentioned later as static zoometry) data and for cow movement

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(dynamic zoometry) data. Equipment used in this research are a paper sheet, pen, ruler, stop-watch, and handy cam. The static measurement focused on the cow body dimension, e.g., length of the body, length of the leg, body width, neck length, etc. The dynamic zoometry is taken when the cow is engaged in physical activity. The measurement focused on cow movement (walking), moving the tail, moving head during drink or eating, and standing up to lying down or vice versa. To obtain detailed measurement, some videos have been taken during the measurement process. Briefly, statistic test for normality and validity data are presented in zoometry data analysis.

Figure 1 exhibits one example of measuring the static zoometry for a dairy cow. All measurers have received training before they start working on the dairy farm. Training included how to measure, understanding zoometry concept, knowing the dairy cattle behaviors, and implementing the animal research ethics. Measurements are made under tight control supervision. The quality control procedures during and after survey are explained afterward.

The research investigated zoometry for dairy cattle for both of static and dynamic zoometry measurements. Zoometry concept is important to understand the dairy cattle lives. Zoometry dimension is defined in both static and dynamic measurement of cattle body dimensions and cattle behaviors. There are 16 dimensions of static zoometry for dairy cattle. **Figure 2a** and **b** defined all the dimension (D_1, D_2, D_3,.., D16) of static zoometry in the 2D Picture. The dimensions D_1 to D_{10} explain the position in the front view of dairy cattle (lengthwise direction), and the dimension of D_{11} to D_{13} describes in the lateral direction of dairy cattle. The D1 is for the height of the head, D2 is the height of the body, D3 is the length of neck + head, D14 is head width, D15 is the length of tail, and D16 is the length of horns.

Table 2 shows some of the results of static zoometry measurement in 16 dimensions as mentioned before with 25 data, respectively. Homogeneity tests are used to ensure when the data collection of cow body size is in a uniform condition without any specific arrangement. According to the data, the average of data and the deviation standard are calculated for all

Figure 1. Dairy cattle zoometry measurement for static and dynamic data.

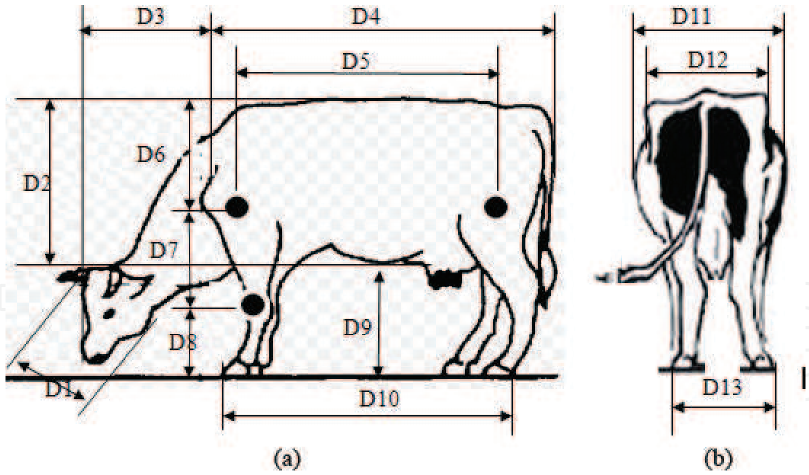

Figure 2. Static zoometry dimensions: (a) front view of cow dimensions (D_1 to D_{10}) and (b) the backside of cow dimensions (D_{11} to D_{13}).

No	Explanation	Dairy cattle dimension				
		1	**2**	**—**	**499**	**500**
D1	Height of the head	36	38	—	38	40
D2	Height of cow body	77	78	—	78	79
D3	Length of the head + neck	104	106	—	104	105
—	—	—	—	—	—	—
D15	Length of the tail	114	113	—	115	120
D16	Length of the corn	9	14	—	10	8

Table 2. Data measurement results from 500 number of source data of cattle for static dairy cattle dimension.

dimensions (D1–D16), as example, D1 has average $\overline{D}$ = 39.64 and deviation standard (σ_1) = 2.68. Moreover, D1 has lower control limit (LCL) = 34.17, and upper control limit (UCL) = 44.47 is categorized in homogeneity data. The same way, the other static cattle dimensions (D2–D16) are also categorized in homogeneity data. As a result the data measurement is ready to use for the next step of sufficient data test.

Sufficient data test for static cattle dimensions is determined based on formula 1. To calculate the number of data requirement (N′), the research select confidence level of collecting data 95% (k = 2), and error = 5% (s = 0.05) which has N′ = 7. As a result the data D1 can be categorized in sufficient data (N′ < N). Using the same way, the data of the other dimension D2–D16 all are categorized in sufficient data:

$$N' = \left[\frac{\left(k/s \sqrt{N \sum_{i=1}^{N} x_i - \left(\sum_{i=1}^{N} x_i \right)^2} \right)}{\sum_{i=1}^{N} x_i} \right]^2 \tag{1}$$

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where N′ = data should be taken.

N = data have been collected

k = level of confidence

s = level of error

x_i = observation data

$$N' = \left[\frac{\left(2/0.05\sqrt{25(966289) - (983)^2}\right)}{983}\right]^2 = 7$$

Human dynamic anthropometry is concerned with the measurement of human work or human motion, e.g., hand movement, sitting down, turning, etc. In analogy with human data, the dynamic zoometry is defined with animal measurement (dairy cattle) on movement and cattle behaviors, e.g., vertical head movement to reach food, the vertical movement to lie down/get up, tail movement, etc. The data is very important in designing the comfortable cattle facilities, e.g., free stall, watering system, floor, house, and feeding rack. **Figure 3** explains the dimensions of dairy cattle dynamic zoometry. There are seven dimensions for D_{17} to D_{23}. Following statements explained dynamic dimension:

- D_{17} dimension is angle scope for vertical movement of a cow head.
- D_{18} dimension is angle scope for horizontal movement of a cow head.
- D_{19} dimension is leg reach on walking movement.
- D_{20} dimension is angle scope for horizontal movement of cow tail.
- D_{21} dimension is length for laying down movement.
- D_{22} dimension is length for raising movement.
- D_{23} dimension is width for lying down or getting up movement.

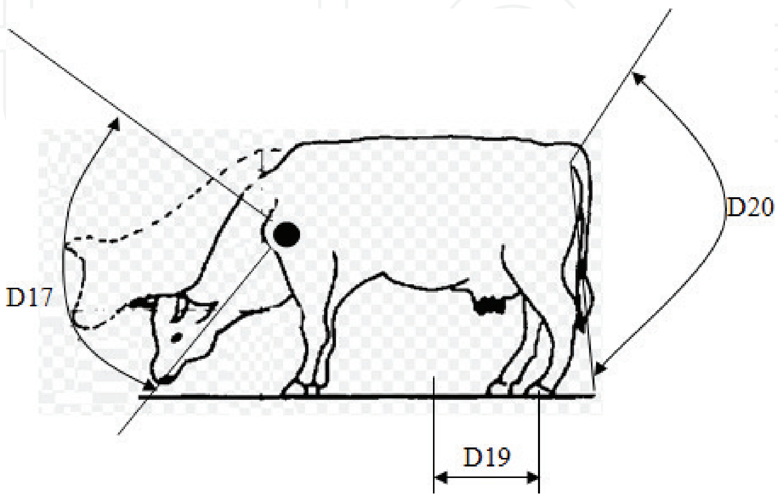

Figure 3. Dairy cattle dynamic zoometry dimensions (D_{17}, D_{19}, D_{20}).

To increase comfort during rising or lie down movement, the resting area must provide cattle with the easy movement for vertical, forward, and lateral movement without obstruction, injury, or fear. A rising motion includes the freedom to lunge forward, bob the head up or down, and stride forward. Resting motion also includes the freedom to lunge forward and bob the head. Each time the cow lies down, a cow puts about two-thirds of body weight on its front knees. Then the knees drop freely to the floor from a height of 20 to 30 centimeter. Therefore it is very important to provide best-quality bedding; as consequence, the cow can painlessly lie down at any time. The easy method to know the comfort level is to look at and check how fast a cow lies down in a cubicle.

3. Back propagation neural network (BPNN)

A neural network can be described as a *black box* that knows how to process input system to create useful outputs. Neural network is defined as "interconnected assembly of simple processing elements, units or nodes, whose functionality is loosely based on the animal neuron [29]. The processing ability of the network is stored in the inter-unit connection strengths, or weights, obtained by a process of adaptation to, or learning from, a set of training patterns." The NN calculation is very complex and difficult to understand by using a mathematical model. Neural network copied the working system of the biological nervous system as an example for the brain to process the information. Other experts define the neural network (NN) as a powerful data modeling tool capable to capture and represent complex input/output relationships involving many factors [30].

The most common neural network model is the multilayer perceptron (MLP) which contains three layers: input layer, hidden layer, and an output layer. This type of neural network is known as a supervised network because it requires the desired output in order to learn. The goal of this type of network is to create a model that correctly maps the input to the output using historical data; therefore, the model can then be utilized to produce an output when the desired output is unknown. The MLP and many other neural networks learn using an algorithm called "back propagation" [31]. The goal of a back propagation neural network (BPNN) is to minimize the error which in the project is shown as a mean square error (MSE). With each presentation, the output of the neural network is compared to the desired output, and an error is computed. This error is then fed back (back propagated) to the neural network and utilized to adjust the weights such that the error decreases with each iteration and the neural model gets increasingly closer to producing the desired output. This process is known as "training." **Figure 4** describes how the BPNN system works to minimize the gap between target and output by adjusting network weight.

BPNN works in three parts of a database called the set of training data, set of cross validation data, and set of testing data. *Training data* is utilized in the neural network to learn the databases' correlation and its function as an input data. *Cross validation data* is utilized to evaluate the performance of the learning process to avoid over-training. *Testing data* is utilized to evaluate the performance of the training when it is complete. Production input data was fed into the trained neural network to produce an output. There is no evidence of references

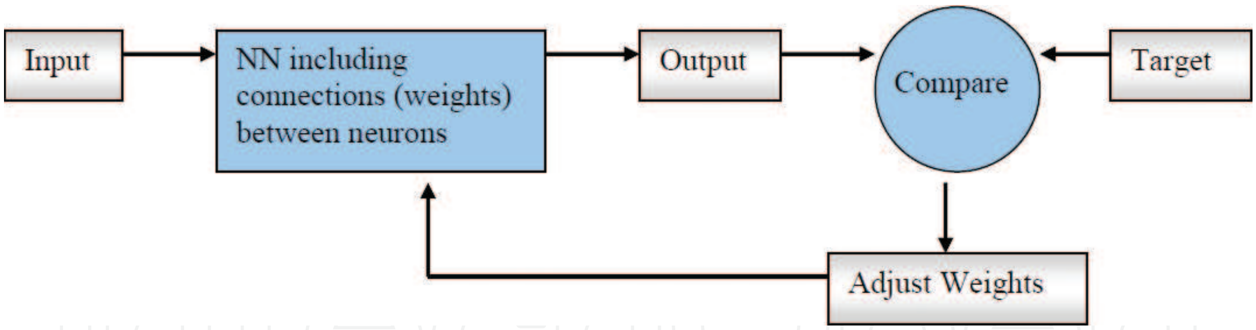

Figure 4. Description of BPNN training the data sets [29].

which explained how to divide the composition of training data, for cross validation and testing. The training data is required for a neural network to predict aerodynamic coefficient [32]. The paper shows manual NN training comparisons based on different transfer functions and training datasets. It is noted that dataset is an important part to obtain a better MSE performance. Commonly, the training data is >60%, the cross validation is ≈15%, and testing data is ≈10%.

Structure of BPNN model is a key performance to accelerate for reducing the gap between NN output and target during training the system. The BPNN structure contains a number of neurons, transfer function, and a number of hidden layers. The common method to create the BPNN structure is by the trial-and-error method. The method will be time-consuming during the training procedure. The optimal design of neural network using the Taguchi Method [33]. Moreover, we can use taguchi method to optimize the structure of BPNN for a limited amount of data [34]. Genetic algorithm (GA) is utilized to optimize the adjustment of the weight values during the training process.

Figure 5 chronologically explains the interconnection between BPNN and GA applications to adjust weight parameter in the quick propagation learning rule. The activities in **Figure 5** contain collection and preparation of data, define robust (optimum) NN architectures, initialize population (connection weights and thresholds), assign input and output values to NN, compute hidden layer values, compute output values, and compute fitness using MSE formula. To find the best NN weight, at the start of the genetic algorithm, an initial population of chromosomes is created. The gene values are assigned to the initial weights of the network, and the network is trained based on the back propagation neural network (BPNN) algorithm. The next step of the algorithm is the fitness values of all the chromosomes of population evaluated; the inverse of MSE is regarded as the fitness function of GA. The individual's genes are modified by crossover and mutation process. These operations result in a new-generation population of chromosomes. The generational process is repeated until convergence condition has been achieved. The weights of the BPNN network are created via a global optimization using GA, which increases the quality and the performance of the BPNN model. In the end, the neural network was trained with selected weight connection. According to the reference [36], the best BPNN structure is described as follows: one hidden layer, initial neuron = 17, tanh transfer function between input and hidden layer, the linear sigmoid transfer function between the hidden layer and output layer, quick propagation learning algorithm,

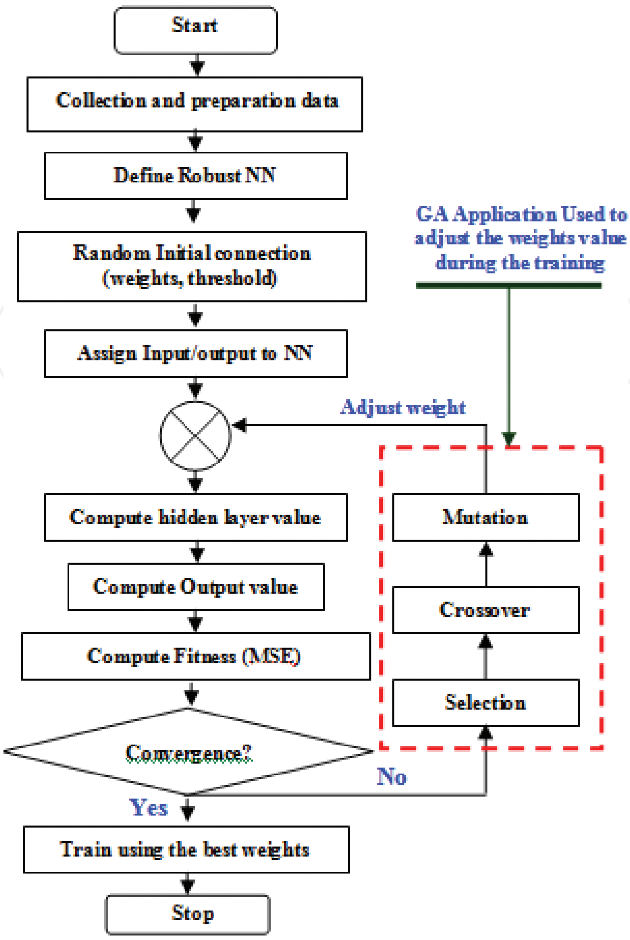

Figure 5. Neuro-genetic algorithm in BPNN development [35].

and 5000 epochs. GA parameters are selected as follows: the Roulette rule is employed to select the best chromosome based on proportionality to its rank, the initial values for learning rate and momentum are 0.5000 and 0.0166, number of population is 50 chromosomes and epoch number was 100 at maximum, initial network weight factor is 0.1074, mutation probability is 0.01, and heuristic crossover was utilized.

4. Construction of prediction model for cattle facilities using BPNN

The dairy cattle facilities should support cattle activities such as resting, drinking, eating, and milking. The facilities must guarantee the cattle will averse being stuck, injuries, and stress behaviors. The best facilities are indicated by cattle comfort level and increasing milk production. Moreover, the floor should not be warm and humid to reduce possible skin injuries and added thermal comfort. The other facility is a watering system; a watering cup should have an opening of at least 0.06 m^2, approximately 30 cm in diameters or similar opening size [13]. It is recommended that the main water supply is ring connected and that the water is under a constant pressure. The best method of watering is supplying via service pipe; it will make sure fresh water is always supplied with a minimum amount of dirt. The free stall is very

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important for cattle to provide comfortable space for rest. Nigel B. Cook [9] research on free stall design for maximum cow comfort reported that 11.3 hours is needed for lying down in the stall and 2.9 hours for standing in the stall a day, in total 14.2 hours per day contact with free stall (around = 59.17%). The cow must have free stall design correctly sized as it correlates with milk production. A lot of farmers reduce stall length and width in order to save construction cost. It will reduce the level of cow comfort and milk production. Free stall should be designed correctly and maintained and should be sloped from front to back and provide a comfortable surface.

To control the steps of the research which are logically right, flowchart of developing and implementing the zoometry concept is presented as can be seen in **Figure 6**. According to the graph, the next step after collecting the static and dynamic data is doing the statistic test for checking the data quality. Manual measuring for dynamics data is time-consuming and costly and requires more energy, e.g., measuring the length for raising movement. The database construction is developed based on **Tables 2** and **3**, **Table 2** as input data and **Table 3** as desired data. As a result, BPNN can predict easily the dynamics zoometry dimension from any inputs of static zoometry dimension. To look for the best neural network structure, at the same time, the GA method is employed during NN training. BPNN module is ready to use to be part of designing the cattle comfort facilities, e.g., free stall, cattle house, etc.

Figure 7 describes BPNN training result using genetic algorithm (GA) optimization in one replication. According to the graph, the training process will stop in 49 generations with mean square error (MSE) = 0.0287. BPNN model is ready to predict any input data to determine output data (dynamics data). The BPNN model is very useful for the user conduct test to determine cow behavior correlated with cow dimensions in design process. The user can put any "normal value" of static cattle dimensions (D_1 to D_{16}) to predict dynamics cattle dimension (D_{17} to D_{23}). As example, the input values are D_1 = 38 cm, D_2 = 78 cm, D_3 = 109 cm, D_4 = 157 cm, D_5 = 137 cm, D_6 = 51 cm, D_7 = 58 cm, D_8 = 41 cm, D_9 = 61 cm, D_{10} = 118 cm, D_{11} = 63 cm, D_{12} = 47 cm, D_{13} = 31 cm, D_{14} = 19 cm, D_{15} = 122 cm, and D_{16} = 14 cm, and produced output values are D_{17} = 52 cm, D_{18} = 214 cm, D_{19} = 54 cm, D_{20} = 121 cm, D_{21} = 312 cm, D_{22} = 301 cm, and

No	Explanation	Dairy cattle dimension (cm)				
		1	2	—	499	500
D17	Vertical head movement (^{0})	50	55	—	43	45
D18	Horizontal head movement (^{0})	200	220	—	225	240
D19	Step walking (cm)	53	72	—	77	64
D20	Cow tail movement (^{0})	120	110	—	112	103
D21	Space for lying down (cm)	313	309	—	312	318
D22	Space for getting up (cm)	300	296	—	299	205
D23	Width space (cm)	132	130	—	120	118

Table 3. Data measurement results from 500 dairy cattle for dynamic dairy cattle dimension.

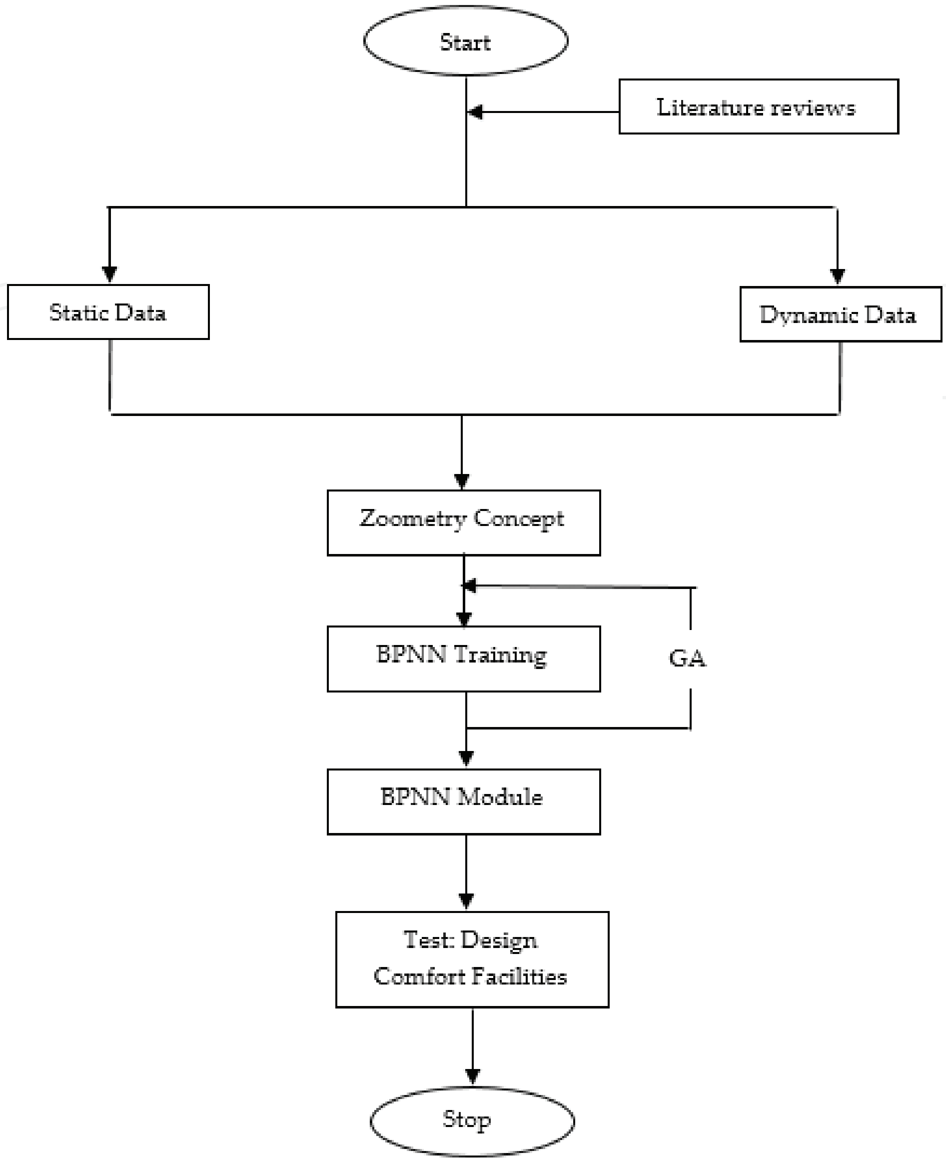

Figure 6. Flowchart of developing and implementing the zoometry concept using BPNN module.

D_{23} = 130 cm. The following stage involved implementing the zoometry concept and BPNN model to evaluate and redesign the cattle facilities. The first step of designing the cattle house is defined the house parameters which are described as follows:

- Length of cattle house (L)

Length of cattle house is defined as the total summation of length for lying down and length for getting up minus cattle length or $L = \bar{D}_{21} + \bar{D}_{22} - (\bar{D}_3 + \bar{D}_4)$. Based on data in **Table 1** for $\bar{D}_3 + \bar{D}_4$ and BPNN test for $\bar{D}_{21} + \bar{D}_{22}$, L has average 346.67 cm and deviation standard σ = 6.71 cm then by using percentile 95th will produce $L_{zoometry}$ = 346.67 cm + 1.64 × 6.71 cm = 357.67 cm.

- Width of cattle house (W)

The width of cattle house is defined as the space for lying down or getting up easily or defined in D_{23}. Based on the data in BPNN test, D_{23} has value = 125.96 cm and deviation

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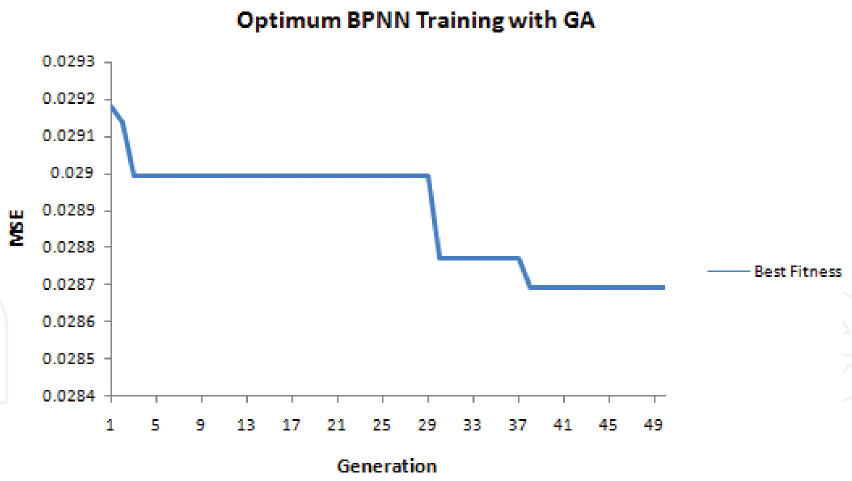

Figure 7. Static and dynamic zoometry training in BPNN-GA application.

standard σ = 3.70 cm and then using percentile 95th will produce $W_{zoometry}$ = 125.96 cm + 1.64 × 3.70 cm = 132.03 cm

- Height of cattle house (H)

Height of cattle house is defined as the summation of $\bar{D}_2 + \bar{D}_9 + (\bar{D}_3 \times \tan(0.5 \times \bar{D}_{17}))$. Based on the data in **Table 1** and BPNN test, H has average 194.64 cm and deviation standard σ = 6.49 cm and then by using percentile 95th will produce $H_{zoometry}$ = 194.64 cm + 1.64 × 6.49 cm = 205.28 cm.

Cattle house design is recommended based on the results of zoometry calculation of length, width, and height. The cattle house design should have minimum value of length = 357.67 cm, width = 132.03 cm, and height = 205.28 cm. The height dimension of cattle house must consider the other factors such as air circulation, lighting, and the other facilities especially in a tropical climate with higher level of temperature and relative humidity. It can increase the heat stress index, which finally reduces milk production. In the United States, climate change that makes higher temperature and humidity than normal is likely to affect milk production because dairy cows are sensitive to excessive temperature and humidity.

5. Conclusion(s)

The paper has successfully developed the concept of zoometry to describe the dimensions of dairy cattle to design facilities. There are two zoometry for static and dynamics condition with a total number of dimensions at 16 and 7. The chapter successfully presented the BPNN training as the complexity of dynamic data (cattle motion behavior) correlated with cattle dimension. The paper also describes how to implement the zoometry concept in order to develop cattle house design. This method could be used to design other facilities such as free stall, watering system, designing floor, and feeding rack.

Using 500 cattle data source, the zoometry concept still fluctuates despite success in homogeny test and data-sufficient test. As consequence, a huge number of dimension data is required to obtain steady zoometry. The zoometry concept will be an important topic of research in the future correlated with cattle comfort and cattle productivity.

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References

[1] Rozenberg S, Body JJ, Bruyère O, Bergmann P, Brandi ML, Cooper C, Reginster JY, et al. Effects of dairy products consumption on health: Benefits and beliefs—A Commentary from the Belgian Bone Club and the European Society for Clinical and Economic aspects of osteoporosis, osteoarthritis and musculoskeletal diseases. Calcified Tissue International. 2016. https://doi.org/10.1007/s00223-015-0062-x

[2] Choi IY, Lee P, Denney DR, Spaeth K, Nast O, Ptomey L, Sullivan DK, et al. Dairy intake is associated with brain glutathione concentration in older adults. American Journal of Clinical Nutrition. 2015;**101**(2):287-293. https://doi.org/10.3945/ajcn.114.096701

[3] Faghih A, Anoosheh M, Ahmadi F, Ghofranipoor F. The effect of boy students' participation on consumption of milk and dairy. Hormozgan Medical Journal. 2007;**10**(4):349-356

[4] Davoodi H, Esmaeili S, Mortazavian AM. Effects of milk and milk products consumption on cancer: A review. Comprehensive Reviews in Food Science and Food Safety. 2013;**12**(3):249-264. https://doi.org/10.1111/1541-4337.12011

[5] Flynn A, Cashman K. Nutritional aspects of minerals in bovine and human milks. In: Fox PF, editor. Advanced Dairy Chemistry, Vol. 3 Lactose, Water, Salts and Vitamins. 2nd ed. London: Chapman & Hall; 1997

[6] Fox PF, Mcsweeney PLH. Dairy Chemistry and Biochemistry. 1998;**1542**(9):478. https://doi.org/10.1007/978-3-319-14892-2

[7] Holt C. Effect of heating and cooling on the milk salts and their interaction with casein. In: Fox PF, editor. Heat Induced Changes in Milk. 2nd ed. Brussels: International Dairy Federation; 1995. pp. 159-178

[8] Öste R, Jägerstad M, Anderson I. Vitamins in milk and milk products. In: Fox PF, editor. Advanced Dairy Chemistry, Vol. 3 Lactose, Water, Salts and Vitamins. 2nd ed. London: Chapman & Hall; 1997

[9] Cook NB, Bennett TB, Nordlund KV. Monitoring indices of cow comfort in free-stall-Houtilized dairy herds. Journal of Dairy Science. 2005;**88**(11):3876-3885. https://doi.org/10.3168/jds.S0022-0302(05)73073-3

[10] Krawczel PD, Klaiber LB, Butzler RE, Klaiber LM, Dann HM, Mooney CS, Grant RJ. Short-term increases in stocking density affect the lying and social behavior, but not the productivity, of lactating Holstein dairy cows. Journal of Dairy Science. 2012;**95**(8):4298-4308. https://doi.org/10.3168/jds.2011-4687

[11] Vazquez OP, Smith TR. Factors affecting pasture intake and Total dry matter intake in grazing dairy cows. Journal of Dairy Science. 2000;**83**(10):2301-2309. https://doi.org/10.3168/jds.S0022-0302(00)75117-4

[12] Jim R. Dairy Facilities and Cow Comfort. Tulare, CA: Veterinary Medicine Teaching and Research Center; 2011

[13] Bridger R. Introduction to Egonomics. Engineering. Vol. 8. 2003. https://doi.org/10.4324/9780203426135

[14] International Organization for Standardization (ISO) (2008), Basic human body measurements for technological design (ISO 7250-1;2008)

[15] Taifa IW, Desai DA. Anthropometric measurements for ergonomic design of students' furniture in India. Engineering Science and Technology: An International Journal. 2017;**20**(1):232-239. https://doi.org/10.1016/j.jestch.2016.08.004

[16] Masson AE, Hignett S, Gyi DE. Anthropometric study to understand body size and shape for plus size people at work. Procedia Manufacturing. 2015;**3**:5647-5654. https://doi.org/10.1016/j.promfg.2015.07.776

[17] Pheasant S, Bodyspace Anthropometry, Ergonomics and the Design of Work Second Edition; 2003

[18] Zhang P, Qint S, Wright DK Novel method of capturing static and dynamic anthropometric data for home design, IEEE; 2005. https://doi.org/10.1109/EURCON.2005.1629990

[19] Kroemer KHE. Engineering anthropometry. Ergonomics. 1989;**32**(7):767-784. https://doi.org/10.1080/00140138908966841

[20] Grant R. Taking advantage of natural behavior improves dairy cow performance. In: Western Dairy Management Conference. 2007. pp. 1-13

[21] Marino L, Allen K. The psychology of cows. Animal Behavior and Cognition. 2017;**4**(44):474-498. https://doi.org/10.26451/abc.04.04.06.2017

[22] Krawczel P, Grant R. Effects of cow comfort on milk quality, productivity, and behavior. 2013. http://articles.extension.org:80/pages/70107/effects-of-cow-comfort-on-milk-quality-productivity-and-behavior

[23] Dairy NZ. Dairy NZ Economic Survey 2007-08. In Report; 2009

[24] Anonymous, Interdisciplinary report. Housing Design for Cattle – Danish Recommendation. Third Edition 2001. The Danish Agricultural Advisory Center, Translated into English and Issued in 2002. 122 pp

[25] Phillips C. Cattle Behaviour and Welfare: 2nd Edition. 2007. https://doi.org/10.1002/9780470752418

[26] Currie WB. Structure and Function of Domestic Animals. CRC Press; 1995

[27] Benham PFJ. Synchronization of behaviour in grazing cattle. Applied Animal Ethology. 1982;**8**(4):403-404. https://doi.org/10.1016/0304-3762(82)90075-X

[28] Michael BJ, John SF, Joseph HP. Facility and Climate Effect on Dry Matter Intake of Dairy Cattle. 5th Western Dairy Management Conference, April 4-6. Las Vegas: Nevada; 2001

[29] Gurney K. An introduction to neural networks. Neurocomputing (Vol. 14). 1997. https://doi.org/10.1016/S0925-2312(96)00046-X

[30] Yu X, Efe MO, Kaynak O. A general backpropagation algorithm for feedforward neural networks learning. IEEE Transactions on Neural Networks/a Publication of the IEEE Neural Networks Council. 2002;**13**(1):251-254. https://doi.org/10.1109/72.977323

[31] Laurene F. Fundamentals of Neural Network. Prentice Hall International, Inc, USA: Florida Institute of Technology; 1994

[32] Rajkumar T, Bardina J. Training Data Requirement for a Neural Network to Predict Aerodynamic Coefficient. NASA Ames research center, Moffet Field, California, USA

[33] Khaw JFC, Lim BS, Lim LEN. Optimal design of neural networks using the Taguchi method. Neurocomputing. 1995;**7**(3):225-245. https://doi.org/10.1016/0925-2312(94)00013-I

[34] Sugiono, Wu MH, Oraifige I. Applying the design of experiment (DoF) to optimise the NN architecture in the car body design system. In: Proceedings of 2011 17th International Conference on Automation and Computing, ICAC 2011

[35] Sugiono, Wu MH, Oraifige I. Employ the Taguchi Method to Optimize BPNN's Architectures in Car Body Design System, American Journal of Computational and Applied Mathematics. 2012;**2**(4):140-151. https://doi.org/10.5923/j.ajcam.20120204.02

[36] Sugiono S, Soenoko R, Riawati L. Investigating the impact of physiological aspect on cow milk production using artificial intelligence. International Review of Mechanical Engineering. 2017;**11**(1). https://doi.org/10.15866/ireme.v11i1.9873