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Estimation of the Distance Travelled While Collecting Bales from a Field Using Artificial Neural Networks (ANN)

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A B S T R A C T
In this paper, data is acquired using the simulation of the collection of bales from a field by the collecting operator. An artificial neural network is then designed using MATLAB software. The inputs of this artificial neural network are the number of bales in the field, the capacity of the wagon transporting the bales, and the length and width of the field while the output is the distance travelled by the machine in the field. After training the network using the simulated data, the network was able to estimate outputs with R=0.988.

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INTRODUCTION

A set of machinery is required for the harvest of the hay. First, the mowers cut the hay. A conditioner could possibly be employed during the mowing or after the hay has been cut. The hay is then swathed with a rake and prepared for baling. The baler converts the swath to bales. The bales are then transported to storage by the wagon. The bale wagon operator must travel a certain distance in the field in order to carry the bales outside the field. A shorter distance translates into lower fuel and time consumption, cost, soil compression and, other adverse effects in farming. In this paper, estimation of this distance is attempted using ANN considering the different factors affecting it. These factors are the number of bales, capacity of the wagon, length of the field, width of the field, and the position of the entrance of the field as well as the distribution of the bales in the field. The distance travelled increases with the number of bales. If the capacity of the wagon increases the number of trips required to transport the bales is reduced and, as a result, the distance travelled will be reduced. Increase of the length and width of the field, as the number of bales remain constant, amount to a lower density of hay. The number and position of the entrances and exits are also a factor in the distance. The distribution of the bales is different in different fields and depends on factors such as the density of the hay in different parts of the field. The estimation of this distance can be used to predict many field management tasks such as the time required for the collection of bales, soil compression and consumption of fuel.

A MATLAB program (Grisso *et al.*, 2007) was used to calculate the distance travelled while collecting bales. A grid with the origin at the field entrance was established and an x-vector and y-vector was created with the coordinates of every bale. A loading sequence was established for the first load. The operator just selected the bales located closest to the field entrance that could be loaded in a “reasonable” sequence. The next load was selected, and this process was continued until all bales were hauled.

Three heuristic algorithms were tested for bale collection: Clarke-Wright savings algorithm (Clarke and Wright, 1964), the Gillett-Miller sweep algorithm (Gillett and Miller, 1974), and an insert algorithm (Kay, 2009). These algorithms were implemented using a logistics toolbox for MATLAB called MatLog (Kay, 2009). These algorithms were compared to one another on the basis of route distance and processor time (Wold, 2011).

Problem:

Let’s assume that there are n bales in a field with given dimensions and these bales must be removed from the field using a wagon. The capacity of the wagon is m. The distribution of the bales in the field is random and the entrance is located at the corner of the field. If n/m is an integer, n/m trips are needed to collect the bales by

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the wagon, otherwise the bales are removed after[n/m]+1trips.For example, if the number of bales is 16, the capacity of the wagon is 6 and dimensions of the field are 3×5.Three trips are needed to remove the bales (two trips with six bales and one trip with four).The origin is considered as the entrance of the field. Figure 1 (right) illustrates 16 bales which are distributed randomly in the field. Figure 1 (left) illustrates a possible route for removing these bales. The total distance for this example is equal to the sum of all the lines shown in the figure 1 (right).

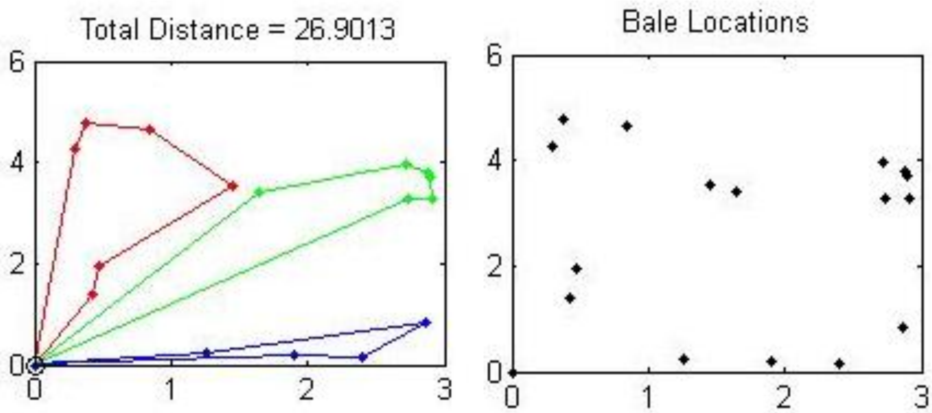

Fig. 1: The locations of 16 bales in a 3×5 field (left)-A possible route (right).

Simulation and Implementation of the Collection of Bales by the Operator

In this section, data used to train the ANN is obtained by simulating of the path of the collection machine in the field. The inputs of algorithm are m, n, the length and width of the field. n 2-dimensional coordinates are produced randomly in the length and the width of field. The distance of the bales from each other and the origin is determined using the following equation: $D = \sqrt{(x_2-x_1)^2 + (y_2-y_1)^2}$.

The operator starts off at the entrance and the first bale encountered is the one closest to the entrance. The second bale would be the one closest to the first bale. This procedure is continued until the full capacity of the wagon is reaches. The next lap begins with the closet remaining bale to the entrance and continues in the same manner as the previous lap. This procedure is continued until all of the bales have been removed from the field. For example, let us assume that there are 6 bales with locations given in Table 1. The distance of these bales from each other is shown in Table 2. If the capacity of the wagon is 4 bales, the order of the collection will be as follows: the first bale is #3 because this bale is the closest to the origin (entrance). The next bale is #4 because this bale is the closest one to #3. Bales #1 and #2 are also picked up following such a procedure until the four bale capacity is full. The first bale in the next lap is #6 because there are only 2 bales remaining (#5 and #6) and #6 is closer to the entrance. Thus the route followed is: 3-4-2-1-6-5. The method used to calculate the distance travelled in this path is shown in Table 3.

Table 1: Cartesian coordinates for 6 bale locations.

	#1	#2	#3	#4	#5	#6
X	0.960877	1.522955	0.966238	1.303081	1.550014	1.458117
Y	0.655248	0.532224	0.10012	0.031471	2.066169	2.109809

Table 2: Distance of the points in Table 1 from each other and from origin.

	(0,0)	#1	#2	#3	#4	#5	#6
(0,0)	0	1.163028	1.613274	0.971411	1.303461	2.582944	2.564644
#1	1.163028	0	0.575384	0.555155	0.711479	1.52898	1.537203
#2	1.613274	0.575384	0	0.704733	0.546899	1.534184	1.578917
#3	0.971411	0.555155	0.704733	0	0.343767	2.050889	2.069008
#4	1.303461	0.711479	0.546899	0.343767	0	2.049628	2.084112
#5	2.582944	1.52898	1.534184	2.050889	2.049628	0	0.101732
#6	2.564644	1.537203	1.578917	2.069008	2.084112	0.101732	0

Table 3: The method used to calculate the distance travelled in route 3-4-2-1-6-5 with a wagon capacity of 4.

(0,0)-3	3-4	4-2	2-1	1-(0,0)	(0,0)-6	6-5	5-(0,0)	Total
0.971411	0.343767	0.546899	0.575384	1.163028	2.564644	0.101732	2.582944	8.849809
Lap #1					Lap #2			

Sample Size:

A program was written in MATLAB for the implementation of the method. The inputs considered in this program are as follows:

-Width of the field: 11 levels (10 to 30 m, increment 2)

-Length of the field: 31 levels (30 to 90 m, increment 2)
-The number of bales: 26 levels (50 to 100 m, increment 2)
-Capacity of the wagon: 5 levels (4 to 8 m)
Sample size: 11×31×26×5=44330

These 44330 samples are used to train an ANN to estimate the distance travelled in the field considering 4 factors (the number of bales, capacity of the wagon, the length and the width of the field).

Design and Simulation of the ANN:

The Neural Network Fitting Tool (MATLAB toolbox) is utilized to estimate the distance travelled in the field.
Data are divided in to three parts (train, verify and test) in the following manner:
-70% for training (31030 samples)
-15% for validation (6650 samples)
-15% for testing (6650 samples)

The network has 4 inputs (the number of bales, capacity of the wagon, length and width of the field) and 1 output (the distance travelled in order to collect the bales from the field). The architecture of the network has one hidden layer and one output layer. The hidden layer has 10 sigmoid neurons while the output layer has one linear neuron(figure 2).

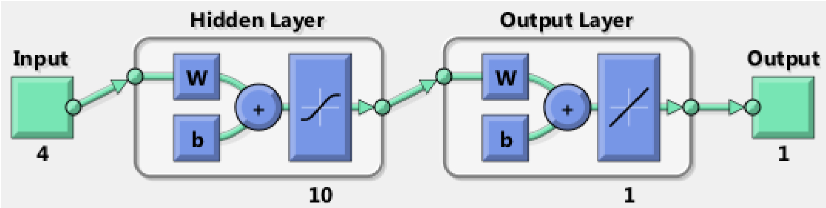

Fig. 2: The ANN architecture for the estimation of the distance travelled.

The training method used is the Levenberg-Marquardt Backpropagation.
The training of the ANN is continued for 167 epochs (Figure 3).

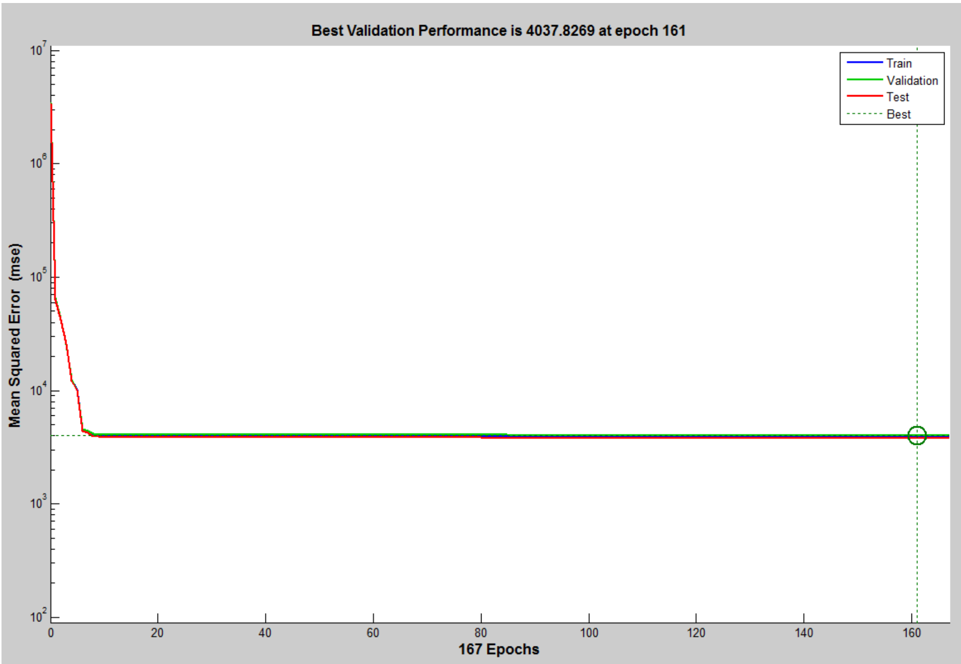

Fig. 3: The procedure of variation Mean Square Error in 167 epochs of training for three classes of data (training, validation and testing).

Supplementary information is presented in Figure 4.

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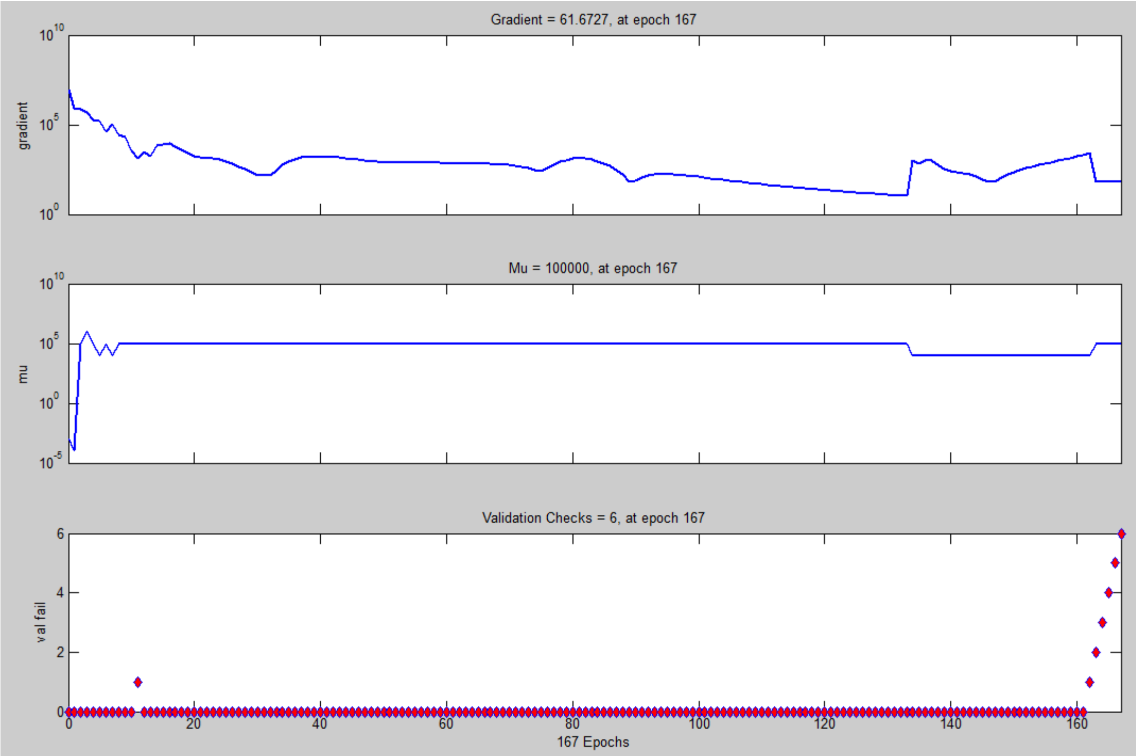

Fig. 4: Supplementary information for training of the ANN.

Results and Conclusions:

Figure 5 shows the error histogram (the difference between the actual distance and the estimated distance by ANN) for the three classes. The histogram shows that the ANN estimation is effective as majority of errors are located in close proximity of zero.

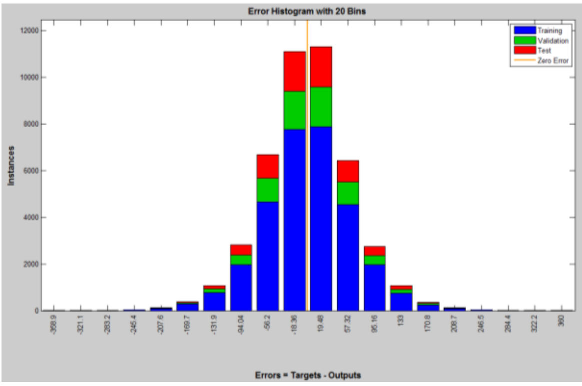

Fig. 5: The error histogram for the three classes of data.

Figure 6 shows the regression line between the estimation of the network and actual data in 4 different parts (train, verify, test and all of data). The values of R (more than 0.987) in all of 4 parts show that network is effective.

Table 4 presents the values of R and MSE for the relationship between the actual value and the estimated value for the three classes of data. Again, it shows that the ANN is effective.

Table 4: Values of R and MSE along with the relationship between the actual value and the estimated value for the three classes of data.

Data	Number	R	MSE	Relation
Train	31030	0.988103	3919.67001	Output=0.988103*target+26
Verify	6650	0.987778	4037.82690	Output=0.987778*target+23
Test	6650	0.988212	3813.05752	Output=0.988212*target+26

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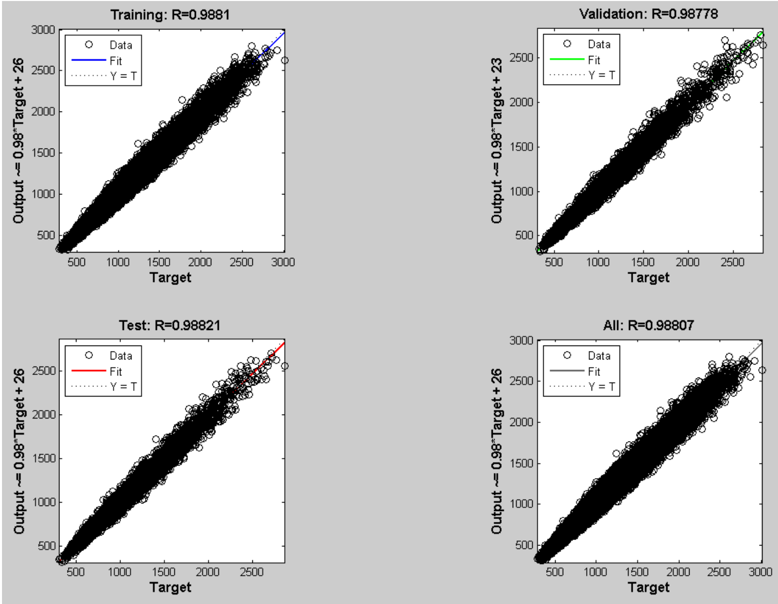

Fig. 6: The linear regression- top, left: training data- top, right: validation data- bottom, right: test data- bottom, right: all of data.

This paper shows that, if the number of bales, capacity of the wagon, the length of field and the width of field are given, the distance travelled in the field can be estimated using an ANN with reasonable accuracy. The inputs of this network are easy to obtain and the output can be useful in many management tasks.

Bale distribution is considered random. Table 5 shows the average and standard deviation for some treatments. The Standard deviation is small and in the result of this, the different distribution in field cannot affect much error.

Table 5: The average and the standard deviation for some treatments.

	The number of bales	Capacity of the wagon	Width	Length	Iterations	Average	Std dev.
1	50	4	15	40	10	693.8058	23.3933
2	50	4	15	80	10	1307.305	116.4615
3	50	4	25	40	10	812.2211	33.49064
4	50	4	25	80	10	1346.811	92.85776
5	50	8	15	40	10	444.1278	21.18847
6	50	8	15	80	10	799.5916	35.49038
7	50	8	25	40	10	530.6577	20.81463
8	50	8	25	80	10	851.8368	37.64156
9	150	4	15	40	10	1904.743	39.10686
10	150	4	15	80	10	3373.002	140.4831
11	150	4	25	40	10	2161.623	90.35168
12	150	4	25	80	10	3651.756	131.0281

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