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The Analysis of Influence Factors of ITO Bar's Ideal Resistance for Multi-Finger Touch Screen

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Abstract

This paper presents an intelligent mechanism which could analyze the influencing factors of touch panel (TP) ITO bar's real resistance. The artificial neural network (NN) is used to catch the complicated and nonlinear relationship between bar's resistance and its relevant manufacturing parameters. A method defined by influence rate (IR) based on the synaptic weights of well-trained neural network is used to obtain the important degree of each influencing factor to ITO bar's real resistance. Such an analysis is expect to help the engineer to precisely set the relevant control parameters on the manufacturing process of ITO bar such that the ideal touch panel with desired film thickness and resistance can be produced. Not only the rate of good product is able to be greatly improved, but also the business cost could be effectively saved. The simulation results clearly show that the method developed indeed has the ability to analyze the influencing degree of each parameter to ITO bar's property accurately.

Keywords: *Intelligent, Influencing Factor, Touch Panel, ITO Bar, Resistance*

1. Introduction

It is well known that since touch panel (TP) was firstly developed in year 1970, TP has been used popularly in various commercial electronic products such as portable computer, mobile phone, and other high-end residential and industrial control equipment [1-5]. Generally, TP could be classified into three categories, i.e. resistive TP, capacitive TP and surface wave TP [4]. In our research, the film printing of resistive TP was studied and reported. Basically, a thin metallic electrically conductive and resistive layer is coated on the TP screen. It can cause a change of the electrical current if the panel was touched by pen or hand. The structure of TP is shown in Fig. 1 [6]. It has a ridged layer and a flexible layer with the spacer dots between two layers. The flexible layer could be touched by the user. The inside surface of ridged and flexible layers is commonly coated with the resistive coating indium tin oxide (ITO) films.

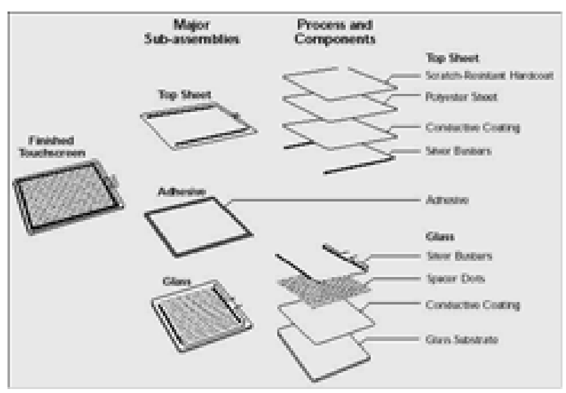

Fig. 1 The structure of resistive touch panel.

The simple illustration of TP is shown as Fig. 2 [4-5]. The manufacturing process of TP includes the film coating and ITO bar's printing and etching [6-14]. Basically, the quality of ITO bar is related to the sensitivity of TP function. The signal processing time and the signal transmission speed could be shorten and improved, if the actual resistance of ITO bar could be able to approximate its ideal resistance effectively. The entire repositioning

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possibility of TP could also be greatly reduced. In general case, the ideal resistance of ITO bar could be calculated by using the following equation [15].

$$\text{Ideal resistance (k}\Omega) = \text{Sheet resistance (k}\Omega)*(\text{Length /Width}) \quad (1)$$

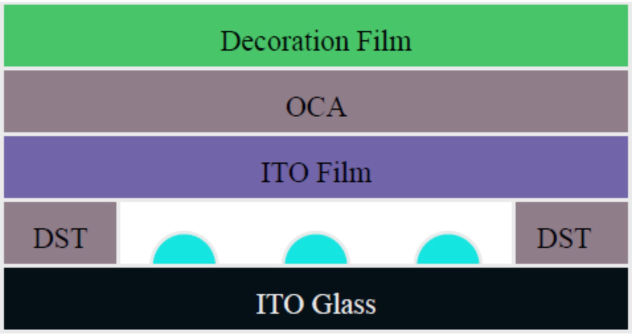

Fig. 2 The simple illustration of touch panel.

In fact, the thickness control of ITO film is a very important work in the whole ITO manufacturing process. The improper thickness of ITO film not only affects the quality of TP, but also causes the waste of printing ink. In most of real cases, the relevant control parameters of film printing process are set by the technician based on personal experience. Undoubtedly, such a parameter setting method easily makes the defective product. Table 1 lists some examples of the possible influencing factors for the ITO film printing [6]. Generally, before executing the film printing work, these parameters are determined by the technician who is full of the printing experiences. For the young technicians having no enough experience in this field, such a setting work is hardly to be done. Thus, how to set these parameters properly so that the ink thickness of film can be effectively controlled becomes a very important work on the real-line manufacturing process of TP.

Table 1: The influencing factors of ITO film printing

Ink Type	Viscosity (pa.s)	Net No. (#)	Length of SC (cm)	Hardness of SC (°)	Degree of SC (°)	Pressure of SC (Kg/cm^2)	Thickness of Film (μm)
3	350	150	2.55	70	63	2.8	31
2	150	150	2.6	70	68	3.2	11
1	250	200	2.85	60	70	3.2	22
2	330	325	2.6	70	60	3.0	8

SC: Scraping Cutter

Except the printing process, the etching process also plays an important role to the resistance control of ITO bar. Table 2 lists the examples of ideal resistance and actual resistance of ITO bar based on different etching rates [15]. It can be clearly found that the different etching rates could cause the different actual resistances for two ITO bars with same length and width. Generally, the etching control parameters are also set by the technician who is full of experience. Thus, the qualified ITO bar then cannot be produced, if the engineer has no experience in this work.

Table 2: The relevant etching parameters of ITO bar

Inputs					Output	Ideal Value
Film Resistance (KΩ)	Bar's Length L (mm)	Bar's Width W (mm)	Ink Thickness (μm)	Etching Rate (m/min)	Bar's Actual Resistance (KΩ)	Bar's Ideal Resistance (KΩ)
0.27	128.68	15.76	35	1.3	2.55	2.205
0.27	128.68	15.76	34	1.3	2.62	2.205
0.27	128.68	15.76	34	2	2.64	2.205
0.27	128.68	15.76	33	2	2.66	2.205
0.5	205.7	13.4	37	1.3	6.71	7.675
0.5	205.7	13.4	35	1.3	6.98	7.675
0.5	205.7	13.4	33	2	6.98	7.675
0.5	205.7	13.4	34	2	6.98	7.675
0.5	163.8	11.68	32	1.3	6.62	7.012
0.5	163.8	11.68	31	1.3	6.61	7.012
0.5	163.8	11.68	32	2	6.58	7.012
0.5	163.8	11.68	31	2	6.58	7.012

In this study, an artificial intelligent (AI) system based on NN technique for the manufacturing process of multi-finger TP is developed. The control of ITO bar's resistance is expected to be analyzed and constructed. The NN model is used to obtain the complicated relationship between the actual resistance and the relevant control parameters of printing and etching processes. The important degree defined by influence rate can help the technician to observe the importance of each influencing factor to ITO resistance. The NN model and its computational method are introduced in Section II, the simulations and results are reported in Section III. Section IV presents the research conclusion and discussion.

2. NN Model

In recent decades, due to the powerful learning and modeling capabilities, NN technique has been widely employed into different areas such as the signal processing and control [15-22]. Through the simple learning process, NN model could generate a nonlinear mapping between input and output pairs bypassing the complicated statistic steps like model hypothesis, identification, estimation of model parameters, and verification. The well trained NN model then can be used for doing the specific work.

The NN model commonly known as multi-layered feed-forward network is used in this research. An example of a three-layered feed-forward NN model shown in Fig. 3 is the selected topology, where Y is the output node, $(H_1, H_2, ..., H_n)$ are hidden nodes and $(x_1, x_2, ..., x_m)$

are inputs. Each layer is connected with the multiplying weight in a feed-forward manner. NN's training is to find the proper weights for all connections such that a desired output could be generated for the corresponding given inputs. In this research, the error back-propagation (BP) learning algorithm is taken for training NN [16-18].

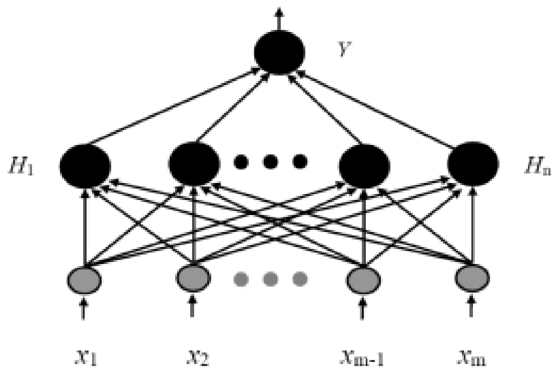

Fig. 3. A three-layered feed-forward NN model.

The computational method defined by for influence rate (IR) is used to find the influencing degree of each input variable to the system output [19-20]. A simple three-layered NN with size 2-3-1 shown in Fig. 4 is used to describe the IR method. In our studies, the sigmoid function is taken to be the activation function for all NN's nodes. It is an increasing function which has the output values within the range [0, 1]. Thus, the following proportional relationships among the inputs (x_1, x_2), the outputs of hidden nodes (r_1, r_2, r_3) and the output node (Y) can be derived.

$$r_j \propto \sum v_{ij} x_i + \theta_j \quad (2)$$

$$Y \propto \sum w_j r_j + \theta_0 \quad (3)$$

$$Y \propto \sum w_j (\sum v_{ij} x_i + \theta_j) + \theta_0 \quad (4)$$

v_{ij} is the strength of connection between hidden node j and input node i; w_j is the strength of connection between hidden node j and output node. θ_0 and θ_j are bias terms. The influence rate (IR) and the percentage influence rate (PIR) of input x_i to the output Y could be defined by

$$\text{IR}_i = \sum_{k=1}^{\text{NT}} \left| \sum_j w_j(k) v_{ij}(k) x_i(k) \right| \quad (5)$$

$$\text{PIR}_i = \text{IR}_i \Big/ \sum_{i=1}^{\text{m}} \text{IR}_i \quad (6)$$

where, NT is the total training number of input and m is the number of categories of input variables.

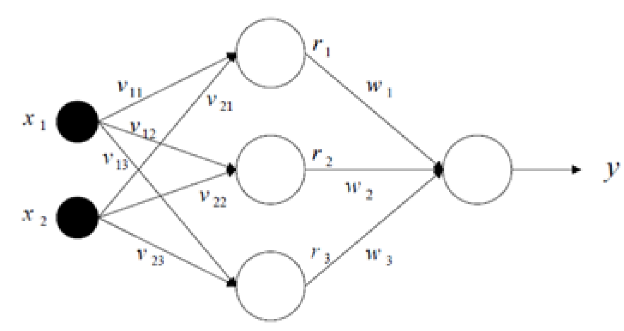

Fig. 4. The structure of 2-3-1 NN model.

3. Simulations

In our study, the complicated relationship between the actual resistance of ITO bar and its relevant etching parameters is expected to be obtained. Totally, there are 60 data sets are collected. In order to fairly demonstrate the research results we expected, 60 data sets are randomly re-organized to be six different groups, i.e. Group-1 to Group-6. In each group, 40 data sets are used for NN's training and the rest of 20 data sets are used for testing. The size of NN model is 5-7-1. The inputs and output of NN model are listed as follows.

Inputs: ITO film resistance, ITO bar's length, ITO bar's width, ink thickness, etching rate
Output: ITO bar's actual resistance

However, before the simulation, the mean absolute percentage error (MAPE) between actual and ideal resistances of ITO bar for the original 60 data sets are calculated by using the following equation firstly. The value of MAPE for 60 data sets is 8.597%. In 60 data sets, the biggest and smallest differences between actual resistance and ideal resistance are 18.047% and 2.075%.

$$\text{MAPE} = \sum_{k=1}^{60} \frac{|\,\text{Actual resistance}\,(k) - \text{Ideal resistance}\,(k)\,|}{\text{Ideal resistance}\,(k)} \times 100\% \quad (7)$$

Table 3 lists the statistics of estimated actual resistance of ITO bar by NN model. From the results shown, it can be found that the average MAPEs of the training data and test data for six groups' actual resistance of ITO bar are 0.73% and 1.03%, respectively. The estimation accuracy is much better than the estimated result by using Eq. (1). In order to analyze the influencing degree of each parameter to the resistance, IR and PIR values of each parameter for six well-trained NN models are calculated. Table 4 lists PIR values for all influencing factors. From the results shown, it is clearly found that film resistance, bar's length and bar's width are three most important influencing factors, the total influencing degree takes about 90%. Consequently, the influencing degree of ink thickness and etching rate takes about 10% which is quite near the real situation.

Table 3: The MAPEs of actual resistance of ITO bar by NN model

Data	MAPE (Training)	MAPE (Test)
Group-1	0.68%	0.94%
Group-2	0.72%	0.96%
Group-3	0.78%	1.16%
Group-4	0.73%	1.03%
Group-5	0.70%	0.95%
Group-6	0.76%	1.11%
Avg.	**0.73%**	**1.03%**

Table 4: The PIR values for all influencing factors

Group	Film Resistance (KΩ)	Bar's Length L (mm)	Bar's Width W (mm)	Ink Thickness (μm)	Etching Rate (m/min)
Group-1	51.54%	14.49%	20.43%	11.78%	1.76%
Group-2	52.70%	14.56%	20.18%	10.81%	1.75%
Group-3	55.12%	13.95%	20.09%	9.12%	1.72%
Group-4	54.24%	14.19%	21.03%	8.77%	1.77%
Group-5	52.90%	14.46%	20.28%	10.61%	1.75%
Group-6	56.02%	13.55%	20.59%	8.15%	1.69%
Avg.	**53.75%**	**14.20%**	**20.43%**	**9.87%**	**1.74%**

Besides, in our study, the similar procedure as [6] is also taken for getting the appropriate manufacturing parameters of ITO film. In our simulations, we assume that the range of ink thickness could be changed from 20 (μm) to 40 (μm) and the etching rate could be varied in the range within 0.5 (m/min) to 2.6 (m/min). The well-trained NN model of Group-4 is used to find the best printing and etching parameters. Table 5 lists some examples of studies [21]. In the table, it is able to find that the actual resistance will be much closer to the ideal resistance, if the values ink thickness and etching rate could be set as the values shown in the table. Thus, such a procedure could help the technician with no experience to make a good manufacturing work.

Table 5: The examples of best parameters observation

Film Resistance (KΩ)	Bar's Length L (mm)	Bar's Width W (mm)	Ink Thickness (μm)	Etching Rate (m/min)	Bar's Actual Resistance (KΩ)	Bar's Ideal Resistance (KΩ)	|Error|	|Error| %
0.27	216.51	10.91	40	2.5	5.352	5.35	0.002	0.037%
0.27	176.08	10.5	36	2.4	4.519	4.52	0.001	0.022%
0.45	167.4	16.26	40	2.6	4.668	4.63	0.038	0.82%
0.45	169.8	9.94	40	2.6	7.886	7.68	0.206	2.68%
0.5	163.8	11.68	20	0.5	6.798	7.012	0.214	3.05%

4. Conclusions

In this research, an intelligent mechanism used for the analysis of TP ITO bar's resistance is developed. NN model is the main tool used to catch the nonlinear and complicated relationship between bar's resistance and its relevant manufacturing parameters during the printing and etching processes. The method defined by IR and PIR values by Eq. (5) and Eq. (6) is used to observe the important degree of each influencing factor to ITO bar's real resistance. From the study results shown, NN model indeed has the ability to estimate more accurate real resistance of ITO bar and the computational method of IR and PIR also can effectively obtain the importance of each influencing factor. It can be concluded that this research do have the potential in the real ITO film manufacturing process.

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