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Research Paper

Combine regression with rough set in the research of influence factor in quad-rotor unmanned aerial vehicle

Ken-Hao Chang, Kun-Li Wen*

Department of Electrical Engineering, Chienkuo Technology University
No. 1, Chiehshou North Road, Changhua, Taiwan.

*Corresponding author. E-mail: klw@ctu.edu.tw.

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ABSTRACT

It is well known that the development of unmanned aerial vehicle has been around for many years. Since the success of the modular system in the last century, the weight, size and price of unmanned airplanes in recent years have greatly reduced. The application is also increasing from the initial defense industry and extended to the live industry and other areas of disaster investigation. But in the analysis of its related performance for unmanned aerial vehicle, what kind of influence factor should be the focus, so far did not see the relevant research in mathematics field. Therefore, the paper analyzes the six common quad-rotor unmanned aerial vehicles used in Taiwan as the research object, based on the stability, photo quality, safety, endurance, portability and friendly using transmission distance and price eight influence factors, takes the first seven factors as the input factors and the eighth factor as the output factor to use regression method to get the positive and negative correlation for the input factors at first. Thereafter, the rough set is integrated in soft computing to find out the kernel of input factors and do the cross validation with the result of traditional regression method, which is used as a reference for the study of quad-rotor unmanned aerial vehicles.

Keywords: Quad-rotor unmanned aerial vehicle, regression, correlation, rough set, kernel.

INTRODUCTION

The so-called quad-rotor unmanned aerial vehicle is a multi-axis aircraft, which uses four rotors to stop in the air, maintain the attitude and fly flat. The main principle is to push the body through the thrust provided by the four rotors. Its four rotor sizes are the same, and the distribution position is close to symmetry. By adjusting the relative speed between the different rotor to adjust the thrust of different positions, and then overcome the reciprocating torque between each rotor, you can control the aircraft and maintain the flight attitude and then complete the various mobile flight journey.

With the development of science and technology and smartphones, it led to the electronic gyroscope, GPS and telex flight control system development. Including the throttle response speed and the use of electric motors as a power system overcome the previous four-axis aircraft bulky shortcomings. Also, it makes the quad-axis aircraft flight stable and flexible. Besides, it can be used both indoors and outdoors. With its small size; light weight and easy to carry, it can enter a variety of harsh environments easily. Hence, it can implement tasks like real-time monitoring and terrain exploration. So, it has now become common fly equipment in this field (Wiki, 2017).

In the past, there were many publications in this field and the paper only lists out several articles, including the control and stabilization of attitude(Liu, 2015; Yang, 2010; Chen, 2012), performance parameters analysis(Chang, 2015), dynamic simulation (Qiu, 2014), application of complementary filter (Li, 2014), fuzzy control of quad-rotor unmanned aerial vehicle (Lin, 2014; Tai, 2013), use regression method and grey system method to analyze the weighting of system influence factor (Chang et al., 2017; Geoffrey and Peck, 2012).

However, there is no relevant article to combine the rough set in soft computing with the regression in traditional method in the weighting analysis of influence factor in the system. Therefore, this paper is the first article to combine rough set with regression method to evaluate the performance of quad-rotor unmanned aerial vehicle.

MATHEMATICS MODEL

Regression method

The regression method is one of the traditional methods in statistics; the analysis steps are listed as:

1) List the equation:

$$y_i(k)=\sum_{j=1}^{N} a_j x_j(k) \quad (1)$$

$$i=1,2,3,\cdots,m,\ k=1,2,3,\cdots,n$$

2) Extend Equation (7), then, we have:

$$\begin{aligned} y_1(1) &= a_1x_1(1)+a_2x_2(1)+\cdots+a_Nx_N(1)\\ y_2(2) &= a_1x_1(2)+a_2x_2(2)+\cdots+a_Nx_N(2)\\ y_3(3) &= a_1x_1(3)+a_2x_2(3)+\cdots+a_Nx_N(3)\\ &\cdots\cdots\\ y_m(n) &= a_1x_1(n)+a_2x_2(n)+\cdots+a_Nx_N(n) \end{aligned} \quad (2)$$

3) Transfer Equation (8) into matrix form:

$$\begin{bmatrix} y_1(1)\\ y_2(2)\\ \vdots\\ y_3(m) \end{bmatrix} = \begin{bmatrix} x_1(1) & x_2(1) & \cdots & x_N(1)\\ x_1(2) & x_2(2) & \cdots & x_N(2)\\ \vdots & \vdots & \ddots & \vdots\\ x_1(n) & x_2(n) & \cdots & x_N(n) \end{bmatrix} \begin{bmatrix} a_1\\ a_2\\ a_3\\ \vdots\\ a_N \end{bmatrix} \quad (3)$$

4) Use $A=(X^TX)^{-1}X^TY$ to get the values of a_N :

Where: $Y=\begin{bmatrix} y_1(1)\\ y_2(2)\\ \vdots\\ y_3(m) \end{bmatrix}$, $A=\begin{bmatrix} a_1\\ a_2\\ a_3\\ \vdots\\ a_N \end{bmatrix}$, $X=\begin{bmatrix} x_1(1) & x_2(1) & \cdots & x_N(1)\\ x_1(2) & x_2(2) & \cdots & x_N(2)\\ \vdots & \vdots & \ddots & \vdots\\ x_1(n) & x_2(n) & \cdots & x_N(n) \end{bmatrix}$

Hence, the values of a_N are the weighting.

Rough set

Pawlak (1982) presented the basic concept of rough set based on the difference between upper approximation and lower approximation in the function of classification (Wen and Lee, 2012). Accordingly, the steps of rough set are given as (Hsu, 2015):

1) Information system

$IS=(U,A)$ is called the information system, where $U=\{x_1,x_2,x_3,\ldots,x_n\}$ is the universe (finite set of objects), and $A=\{a_1,a_2,a_3,\ldots,a_m\}$ is the set of attributes.

2) Information function

If there exists a mapping $f_a:U\rightarrow V_a$, then, V_a is the set of values of *a*, called the domain of attribute a .

3) Discrete calculation

The mathematical model is defined as:

$$t=\frac{V_{\max}-V_{\min}}{k} \quad (4)$$

Where $V_{\max}$ is the maximum value in the data and $V_{\min}$:is the minimum value in the data.

According to the results, we can acquire the intervals corresponding to the attribute value as:

$$\{[d_0,d_1],[d_1,d_2],\cdots,[d_{k-1},d_k]\} \quad (5)$$

Where: $d_0=V_{\min},d_k=V_{\max},d_{i-1}<d_i,\quad i=1,2,3,\cdots,k$; k is the grade of discrete.

4) Lower approximations and upper approximations

If $A\subseteq U$, then, the lower approximations and upper approximations are defined as:

$$\underline{R}(A)=\{x\in U\,|\,[x]_R\subseteq A\}=\bigcup\{[x]_R\in\frac{U}{R}\,|\,[x]_R\subseteq A\},\quad [x]_R=\{y\,|\,xRy\} \quad (6)$$

$$\overline{R}(A)=\{x\in U\,|\,[x]_R\cap A\neq\phi\}=\bigcup\{[x]_R\in\frac{U}{R}\,|\,[x]_R\cap A\neq\phi\},\quad [x]_R=\{y\,|\,xRy\} \quad (7)$$

Table 1: The specification of six quad-rotor unmanned aerial vehicle.

S/No	Specification/brand	DJI Phantom 3 Standard	Millet machine	Ehang Ghost 2
1	Price	US:450	US:400	US:525
2	Diagonal distance	350 mm	434 mm	350 mm
3	Maximum fly time	23 min	27 min	25 min
4	Weight	1,280 g	1,400 g	1,150 g
5	Maximum horizontal fly speed	16.5 m/s	18 m/s	19.5 m/s
6	Remote distance	2000 m	1000 m	1,000 m
7	Transmission distance	4000 m	1000 m	500 m
S/No	Specification/brand	GHOST+ X450	Xiro Xplorer V	Walkera Scout X4
1	Price	US:1,300	US:930	US:900
2	Diagonal distance	450 mm	350 mm	400 mm
3	Maximum fly time	25 min	20 min	25 min
4	Weight	2,250 g	1220 g	1770 g
5	Maximum horizontal fly speed	18 m/s	15 m/s	19.5 m/s
6	Remote distance	1,000 m	500 m	1,500 m
7	Transmission distance	1,000 m	500 m	1,000 m

Table 2: The data of the six experienced experts.

Expert	Experience	Qualifications
S(1)	Over 20 years	Chief of UAV test pilot
S(2)	Over 20 years	UAV external pilot and test pilot
S(3)	14 years	UAV external pilot and test pilot
S(4)	12 years	UAV external pilot and test pilot
S(5)	11 years	UAV external pilot and test pilot

In other words, the lower approximation of a set is the set of all elements that surely belong to *U*, whereas the upper approximation of U is the set of all elements that possibly belong to *U*.

5) Indiscernibility

An indiscernibility relation is defined as for any x_i and x_j and if x_i is identical to x_j, then x_i and x_j have all the same properties.

6) Positive, negative and boundary

According to the aforementioned data, the positive, negative and boundary are defined as:

$$POS_R(X)=\underline{R}(X),\quad NEG_R(X)=U-\overline{R}(X),\quad BN_R(A)=\underline{R}(A)-\overline{R}(A)$$

(8)

7) Dependents

The dependents of the attributes are defined as:

$$\gamma_c(D)=\frac{|posc(D)|}{U} \tag{9}$$

Meaning that, under $a\in C$, the ratio is in the whole set.

8) Significance

Under $S=(U,C\cup D,V,f)$ and $a\in C$, the significant value of the attributes is defined as:

$$\sigma_{(C,D)}(a)=\frac{\gamma_c(D)-\gamma_{c-\{a\}}(D)}{\gamma_c(D)} \tag{10}$$

Example: The quad-rotor unmanned aerial vehicle

The six kinds of quad-rotor unmanned aerial vehicle

This paper further describes the most common quad-rotor unmanned aerial vehicle as the research object (Chang and Wen, 2017).

CALCULATION AND ANALYSIS

Data pre-processing

Table 2 shows the paper build up the expert's system to first evaluate the influence. Next, five aero experts analyze and evaluate eight factors of stability, photo quality, safety,

Table 3: The values of DJI phantom 3 standard.

Expert	Stability	Photo quality	Safety	Endurance	Portability	Friendly using	Transmission distance	Price
S(1)	9	8	7	7	8	8	9	7
S(2)	8	8	7	6	7	8	8	8
S(3)	9	9	9	9	6	7	7	6
S(4)	8	8	8	7	9	7	7	7
S(5)	8	9	7	7	7	8	8	7

Table 4: The values of millet machine.

Expert	Stability	Photo quality	Safety	Endurance	Portability	Friendly using	Transmission distance	Price
S(1)	9	6	6	8	8	7	8	7
S(2)	7	7	7	7	8	7	7	8
S(3)	6	6	6	5	6	5	5	7
S(4)	8	7	8	8	7	7	6	6
S(5)	6	7	7	7	8	8	7	8

Table 5: The values of Ehang Ghost 2.

Expert	Stability	Photo quality	Safety	Endurance	Portability	Friendly using	Transmission distance	Price
S(1)	8	7	6	6	6	6	7	6
S(2)	6	7	6	6	6	7	7	7
S(3)	6	5	5	6	6	5	4	5
S(4)	7	9	7	7	8	8	6	7
S(5)	6	8	6	7	5	5	6	7

Table 6: The values of GHOST+ X450.

Expert	Stability	Photo quality	Safety	Endurance	Portability	Friendly using	Transmission distance	Price
S(1)	7	7	7	6	6	7	7	3
S(2)	6	7	7	6	6	7	7	5
S(3)	6	5	5	7	6	5	5	4
S(4)	8	8	7	7	7	7	6	4
S(5)	4	8	3	6	3	3	2	3

endurance, portability, friendly using, transmission distance and price; the evaluation method is a 10-point Likert Scale and Tables 3 to 8 show the results of the six kinds of quad-rotor unmanned aerial vehicle.

Regression

Based on the evaluation data from Tables 3 to 8, the mean data under the same basis are rearranged and Table 9 shows the results. Based on Table 9, the analysis steps are:

- Build up the original sequence, the price as the independent factor, hence:

$y =$ Price= (7.0, 7.2, 6.4, 3.8, 5.2, 5.2)

And the input factors are:

$x_1 =$ Stability= (8.4, 7.2, 6.6, 6.2, 6.8, 7.0);

$x_2 =$ Photo quality= (8.4, 6.6, 7.2, 7.0, 6.2, 6.2);

$x_3 =$ Safety = (7.6, 6.8, 6.0, 5.8, 6.4, 6.2);

Table 7: The values of Xiro Xplorer V.

Expert	Stability	Photo quality	Safety	Endurance	Portability	Friendly using	Transmission distance	Price
S(1)	7	6	7	5	6	6	7	4
S(2)	7	6	6	6	6	6	7	6
S(3)	6	5	7	5	6	5	6	6
S(4)	8	7	7	6	8	7	5	5
S(5)	6	7	5	5	5	6	2	5

Table 8: The values of Walkera Scout X4.

Expert	Stability	Photo quality	Safety	Endurance	Portability	Friendly using	Transmission distance	Price
S(1)	8	6	6	6	7	6	8	5
S(2)	8	6	6	6	6	6	8	6
S(3)	6	5	7	5	6	5	4	5
S(4)	8	7	7	7	7	6	7	5
S(5)	5	7	5	8	6	6	6	5

Table 9: The analysis data after rearrange of six quad-rotor unmanned aerial vehicle.

Expert	Stability	Photo quality	Safety	Endurance	Portability	Friendly using	Transmission distance	Price
Q_1	8.4	8.4	7.6	7.2	7.4	7.6	7.8	7
Q_2	7.2	6.6	6.8	7.0	7.4	6.8	6.6	7.2
Q_3	6.6	7.2	6.0	6.4	6.2	6.2	6	6.4
Q_4	6.2	7.0	5.8	6.4	5.6	5.8	5.4	3.8
Q_5	6.8	6.2	6.4	5.4	6.2	6.0	5.4	5.2
Q_6	7.0	6.2	6.2	6.4	6.4	5.8	6.6	5.2

Where: Q_1: DJI Phantom 3 Standard .Q_2: Millet machine. Q_3: Ehang Ghost 2. Q_4: GHOST+ X450. Q_5: Xiro Xplorer V. Q_6: Walkera Scout X4.

$x_4 =$ Endurance= (7.2, 7.0, 6.4, 6.4, 5.4, 6.4);

$x_5 =$ Portability= (7.4, 7.4, 6.2, 5.6, 6.2, 6.4);

$x_6 =$ Friendly using= (7.6, 6.8, 6.2, 5.8, 6.0, 5.8);

$x_7 =$ Transmission distance= (7.8, 6.6, 6, 5.4, 5.4, 6.6).

- Substitute into equation (7), then we have:

$$7.0 = 8.4\times a_1 + 8.4\times a_2 + 7.6\times a_3 + 7.2\times a_4 + 7.4\times a_5 + 7.6\times a_6 + 7.8\times a_7;$$

$$7.2 = 7.2\times a_1 + 6.6\times a_2 + 6.8\times a_3 + 7.0\times a_4 + 7.4\times a_5 + 6.8\times a_6 + 6.6\times a_7;$$

$$6.4 = 6.6\times a_1 + 7.2\times a_2 + 6.0\times a_3 + 6.4\times a_4 + 6.2\times a_5 + 6.2\times a_6 + 6.0\times a_7;$$

$$3.8 = 6.2\times a_1 + 7.0\times a_2 + 5.8\times a_3 + 6.4\times a_4 + 5.6\times a_5 + 5.8\times a_6 + 5.4\times a_7;$$

$$5.2 = 6.8\times a_1 + 6.2\times a_2 + 6.4\times a_3 + 5.4\times a_4 + 6.2\times a_5 + 6.0\times a_6 + 5.4\times a_7;$$

$$5.2 = 7.0\times a_1 + 6.2\times a_2 + 6.2\times a_3 + 6.4\times a_4 + 6.4\times a_5 + 5.8\times a_6 + 6.6\times a_7.$$

- Transfer the aforementioned equations into matrix form:

$$\begin{bmatrix} 7.0 \\ 7.2 \\ 6.4 \\ 3.8 \\ 5.2 \\ 5.2 \end{bmatrix} = \begin{bmatrix} 8.4 & 8.4 & 7.6 & 7.2 & 7.4 & 7.6 & 7.8 \\ 7.2 & 6.6 & 6.8 & 7.0 & 7.4 & 6.8 & 6.6 \\ 6.6 & 7.2 & 6.0 & 6.4 & 6.2 & 6.2 & 6.0 \\ 6.2 & 7.0 & 5.8 & 6.4 & 5.6 & 5.8 & 5.4 \\ 6.8 & 6.2 & 6.4 & 5.4 & 6.2 & 6.0 & 5.4 \\ 7.0 & 6.2 & 6.2 & 6.4 & 6.4 & 5.8 & 6.6 \end{bmatrix} \begin{bmatrix} a_1 \\ a_2 \\ a_3 \\ a_4 \\ a_5 \\ a_6 \\ a_7 \end{bmatrix}$$

And use $A = (X^T X)^{-1} X^T Y$ to calculate the values of $a_1 \sim a_7$.

Table 10: The correlation of analysis factor.

Factor	Stability	Photo quality	Safety	Endurance	Portability	Friendly using	Transmission distance
Weighting	-0.5438	1.4131	-3.4056	-2.1359	4.4761	0.3924	0.6223
Correlation	Negative	Positive	Negative	Negative	Positive	Positive	Positive

Table 11: The results of four grades.

Object/factor	Stability (R_1)	Photo quality (R_2)	Safety (R_3)	Endurance (R_4)	Portability (R_5)	Friendly using (R_6)	Transmission distance (R_7)	Price (D)
$Q_1(x_1)$	4	4	4	4	4	4	4	4
$Q_2(x_2)$	2	1	3	4	4	3	1	4
$Q_3(x_3)$	1	2	1	3	2	1	1	4
$Q_4(x_4)$	1	2	1	3	1	1	1	1
$Q_5(x_5)$	2	1	2	1	2	1	1	2
$Q_6(x_6)$	2	1	1	2	2	1	1	2

Table 10 shows the results.

$$X=\begin{bmatrix} 8.4 & 8.4 & 7.6 & 7.2 & 7.4 & 7.6 & 7.8 \\ 7.2 & 6.6 & 6.8 & 7.0 & 7.4 & 6.8 & 6.6 \\ 6.6 & 7.2 & 6.0 & 6.4 & 6.2 & 6.2 & 6.0 \\ 6.2 & 7.0 & 5.8 & 6.4 & 5.6 & 5.8 & 5.4 \\ 6.8 & 6.2 & 6.4 & 5.4 & 6.2 & 6.0 & 5.4 \\ 7.0 & 6.2 & 6.2 & 6.4 & 6.4 & 5.8 & 6.6 \end{bmatrix} \quad Y=\begin{bmatrix} 7.0 \\ 7.2 \\ 6.4 \\ 3.8 \\ 5.2 \\ 5.2 \end{bmatrix},$$

Where:

$$A=\begin{bmatrix} a_1 \\ a_2 \\ a_3 \\ a_4 \\ a_5 \\ a_6 \\ a_7 \end{bmatrix}$$

Rough set method

Also based on the data in Table 9, the discrete is taken at first and subsequently, 4 grades are taken as the analysis data and Table 11 shows the results. According to the data in Table 11, the analysis steps are listed as:

1) Calculate the set of attribute factors given as:

$$\frac{U}{C}=\frac{U}{\{R_1,R_2,R_3,R_4,R_5,R_6,R_7\}}=\{\{x_1\},\{x_2\},\{x_3\},\{x_4\},\{x_5\},\{x_6\}\}$$

2) Calculate the set of decision factor:

$$\frac{U}{D}=\{\{x_1,x_2,x_3\},\{x_4\},\{x_5,x_6\}\}=\{X_1,X_2,X_3\}.$$

Hence, $pos_C(D)=\{\{x_1\},\{x_2\},\{x_3\},\{x_4\},\{x_5\},\{x_6\}\}$, substitute into Equation (8), then, we can get $\gamma_c(D)=\frac{|pos_C(D)|}{|U|}=\frac{6}{6}=1$.

3) Analyze the attribute for each factor:

(1) Omit R_1:

$$\frac{U}{C}=\frac{U}{\{R_2,R_3,R_4,R_5,R_6,R_7\}}=\{\{x_1\},\{x_2\},\{x_3\},\{x_4\},\{x_5\},\{x_6\}\}$$

$$\frac{U}{D}=\{\{x_1,x_2,x_3\},\{x_4\},\{x_5,x_6\}\}=\{X_1,X_2,X_3\}$$

Hence, $pos_C(D)=\{\{x_1\},\{x_2\},\{x_3\},\{x_4\},\{x_5\},\{x_6\}\}$, substitute into Equation (9), then:

$\gamma_{c-\{R_1\}}(D)=\frac{|pos_C(D)|}{|U|}=\frac{6}{6}=1$, mean the significant of R_1 is $\sigma_{(C,D)}(R_1)=\frac{1-1}{1}=0$.

(2) Omit R_2

$\frac{U}{C}=\frac{U}{\{R_1,R_3,R_4,R_5,R_6,R_7\}}$ ={{ x_1}, {x_2},{x_3},{x_4},{x_5},{x_6}}

$\frac{U}{D}$ ={{ x_1, x_2, x_3},{x_4},{x_5, x_6}}={ X_1, X_2, X_3}

Hence, $pos_C(D)$ ={{ x_1},{x_2},{x_3},{x_4},{x_5},{x_6}}, substitute into Equation (9), then:

$\gamma_{c-\{R_2\}}(D)=\frac{|pos_C(D)|}{|U|}=\frac{6}{6}=1$, mean the significant of R_2 is $\sigma_{(C,D)}(R_2)=\frac{1-1}{1}=0$.

(3) Omit R_3

$\frac{U}{C}=\frac{U}{\{R_1,R_2,R_4,R_5,R_6,R_7\}}$ ={{ x_1}, {x_2},{x_3},{x_4},{x_5},{x_6}}

$\frac{U}{D}$ ={{ x_1, x_2, x_3},{x_4},{x_5, x_6}}={ X_1, X_2, X_3}

Hence, $pos_C(D)$ ={{ x_1},{x_2},{x_3},{x_4},{x_5},{x_6}}, substitute into Equation (9), then:

$\gamma_{c-\{R_3\}}(D)=\frac{|pos_C(D)|}{|U|}=\frac{6}{6}=1$, mean the significant of R_3 is $\sigma_{(C,D)}(R_3)=\frac{1-1}{1}=0$.

(4) Omit R_4

$\frac{U}{C}=\frac{U}{\{R_1,R_2,R_3,R_5,R_6,R_7\}}$ ={{ x_1}, {x_2},{x_3},{x_4},{x_5},{x_6}}

$\frac{U}{D}$ ={{ x_1, x_2, x_3},{x_4},{x_5, x_6}}={ X_1, X_2, X_3}

Hence, $pos_C(D)$ ={{ x_1},{x_2},{x_3},{x_4},{x_5},{x_6}}, substitute into Equation (9), then:

$\gamma_{c-\{R_4\}}(D)=\frac{|pos_C(D)|}{|U|}=\frac{6}{6}=1$, means the significant of R_4 is $\sigma_{(C,D)}(R_4)=\frac{1-1}{1}=0$.

(5) Omit R_5

$\frac{U}{C}=\frac{U}{\{R_1,R_2,R_3,R_4,R_6,R_7\}}$ ={{ x_1}, {x_2},{x_3, x_4},{x_5},{x_6}}

$\frac{U}{D}$ ={{ x_1, x_2, x_3},{x_4},{x_5, x_6}}={ X_1, X_2, X_3}

Hence, $pos_C(D)$ ={{ x_1}, {x_2},{x_5},{x_6}, substitute into Equation (9), then:

$\gamma_{c-\{R_5\}}(D)=\frac{|pos_C(D)|}{|U|}=\frac{4}{6}=\frac{2}{3}=\frac{6}{6}=1$, means the significant of R_5 is $\sigma_{(C,D)}(R_5)=\frac{1-\frac{2}{3}}{1}=\frac{1}{3}=0.3333$.

(6) Omit R_6

$\frac{U}{C}=\frac{U}{\{R_1,R_2,R_3,R_4,R_5,R_7\}}$ ={{ x_1}, {x_2},{x_3},{x_4},{x_5},{x_6}}

$\frac{U}{D}$ ={{ x_1, x_2, x_3},{x_4},{x_5, x_6}}={ X_1, X_2, X_3}

Hence, $pos_C(D)$ ={{ x_1},{x_2},{x_3},{x_4},{x_5},{x_6}}, substitute into Equation (9), then:

$\gamma_{c-\{R_6\}}(D)=\frac{|pos_C(D)|}{|U|}=\frac{6}{6}=1$, means the significant of R_6 is $\sigma_{(C,D)}(R_6)=\frac{1-1}{1}=0$.

(7) Omit R_7

$\frac{U}{C}=\frac{U}{\{R_1,R_2,R_3,R_4,R_5,R_6\}}$ ={{ x_1}, {x_2},{x_3},{x_4},{x_5},{

Table 12: The significant of influence factor under four grades.

Grade/factor	Stability	Photo quality	Safety	Endurance	Portability	Friendly using	Transmission distance
Four grades	0	0	0	0	0.3333	0	0

Figure 1: DJI Phantom 3 standard.

x_6}}

$\frac{U}{D}$ ={{ x_1, x_2, x_3 },{ x_4 },{ x_5, x_6 }}={ X_1, X_2, X_3 }

Hence, $pos_C(D)$ ={{ x_1 },{ x_2 },{ x_3 },{ x_4 },{ x_5 },{ x_6 }}, substitute into Equation (9), then:

$\gamma_{c-\{R_7\}}(D)=\frac{|pos_C(D)|}{|U|}=\frac{6}{6}=1$, means the significant of R_7 is $\sigma_{(C,D)}(R_7)=\frac{1-1}{1}=0$.

Table 12 shows the final results.

The verification using toolbox

Figures 7 and 8 shows that the paper uses the self-development toolbox to verify the final results (Wen and You, 2017).

CONCLUSION

The 21st century has witnessed the popular use of soft computing in a variety of engineering fields. However, there have been few models which integrate soft computing and traditional computing. Market-wide, there are more than one hundred types of quad-rotor unmanned aerial vehicles with individual weights ranging from several grams to tens of kilograms. Needless to say, each type of aerial vehicle has its own strength and weakness. So far, however, there has been no analysis integrating both traditional and soft computing. Therefore, the mathematical analysis model proposed by the paper can apply to such study. Six impact factors of the quad-rotor unmanned aerial vehicle are first derived from the empirical mathematical analysis. Concerning sales price, photo quality, portability friendly using and transmission distance are found to be positive correlation, while stability, safety and endurance are found to be negative correlation. The traditional explanation of regression at its best can only point out whether there exists positive or negative correlation. According to the mathematical analysis by the rough set, portability is the core of the quad-rotor unmanned aerial vehicle. This conforms to the expert's regression analysis, which shows that portability is positive correlation, with coefficient value being at 4.4771. The mathematical model applied by the expert, therefore, is reasonable.

In addition to implementing the theory for computing and analysis, the paper also applies the toolbox developed by the C-language, thus, facilitating analysis and computation of a huge amount of data. This is one of the

Figure 2: Millet machine.

Figure 3: Ehang Ghost 2.

Figure 4: GHOST+ X450.

Figure 5: Xiro Xplorer V.

Figure 6: Walkera Scout X4.

contributions made by the paper.

The paper has its limitations. On the one hand, it refers only to six types of quad-rotor unmanned aerial vehicles; on the other hand, it collects opinions from only a few experts. The result of analysis is nevertheless acceptable. Forthcoming study is suggested to take more types into consideration, collect opinions from more experts and postulate more influence factors. In furtherance, other soft computing mathematical models, such as fuzzy set theory are suggested to implement and make the result more

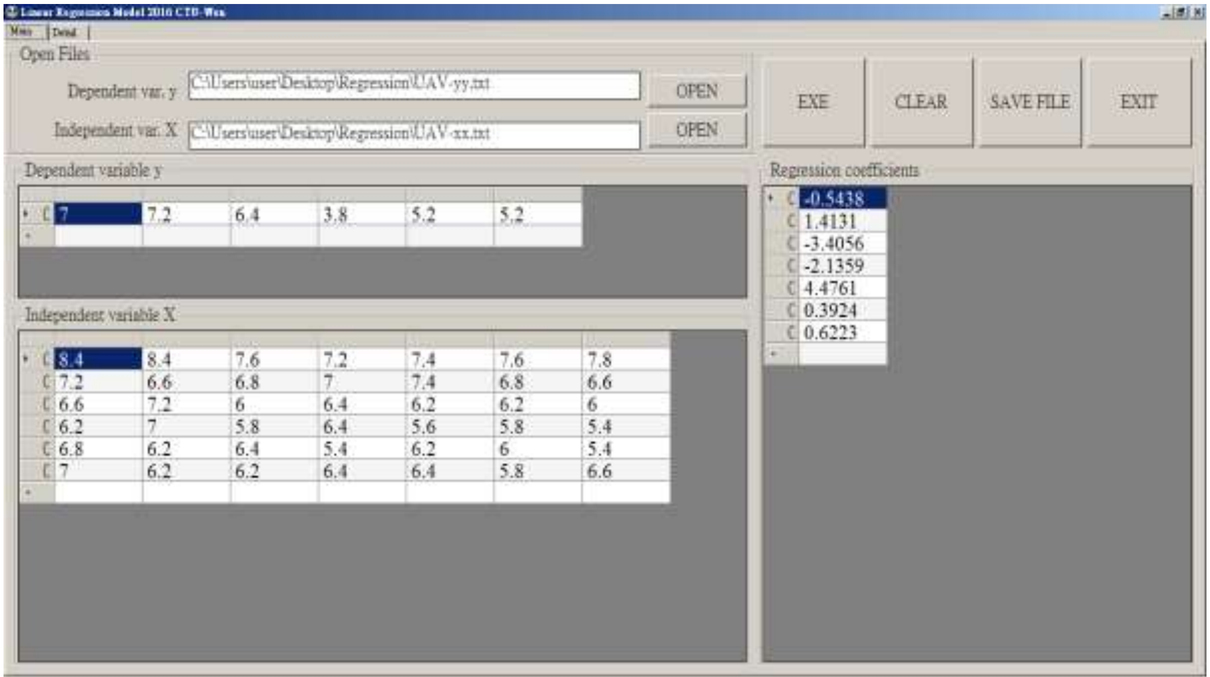

Figure 7: The verification by using regression toolbox.

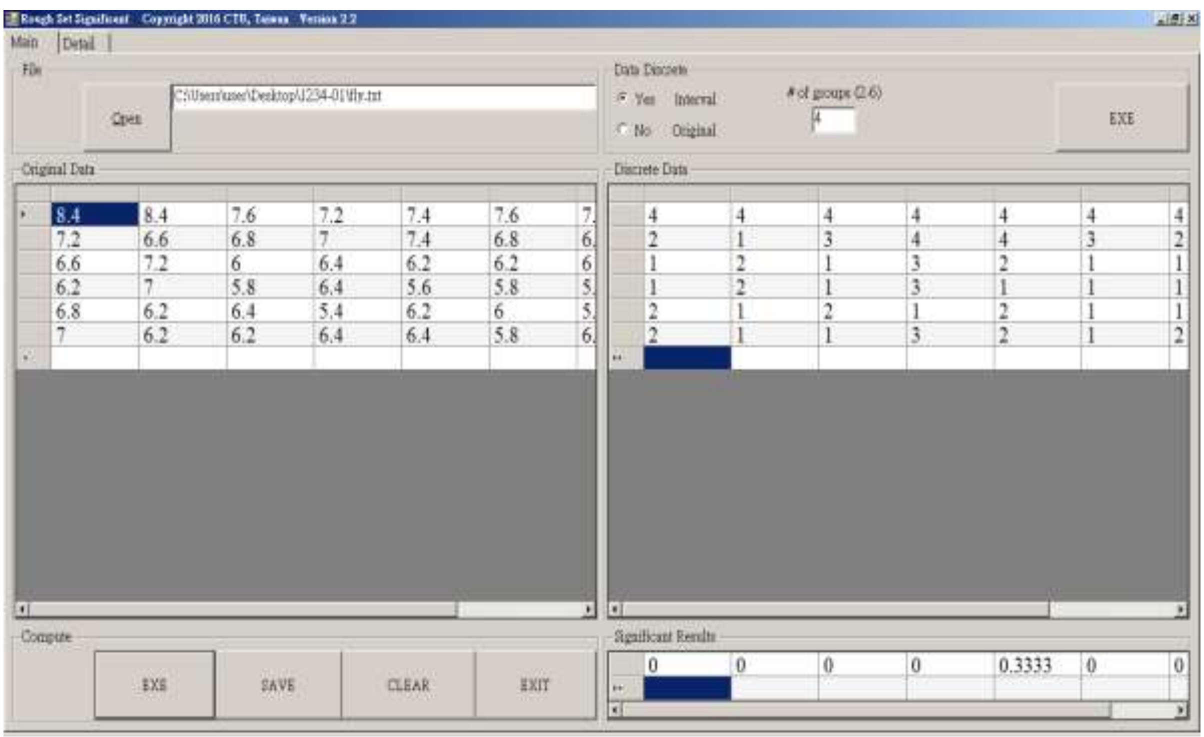

Figure 8: The verification by using rough set toolbox.

convincing.

REFERENCES

Chang KH, Wang JR, Wen KL (2017). The analysis of influence factor in quad-rotor unmanned aerial vehicle by using regression method (in press). *J. Quant. Manag.* 13(1):

Chang KH, Wen KL (2017). Applying grey relational grade and regression in the study of quad-rotor unmanned aerial vehicle. J. Grey Syst. 20(3): 127-134.

Chang KH, Wen KL, You ML (2017). Applying grey relational grade and

GM (0,N) to analyze the C/P value of quad-rotor unmanned aerial vehicle. *Proc. Int. Conf Eng. Natural Sci.*

Chang WJ (2015). *Study of quadrotor UAVs performance parameters analysis*, Master thesis, Department of Aeronautical Engineering, Tamkang University New Taipei City.

Chen YH (2012). *On the stability and control of a quadrotor*, Master thesis, Department of Aeronautical Engineering, Feng Chia University, Taichung.

Geoffrey VG, Peck EA (2012). *Introduction to linear regression analysis*, Wiley, USA.

Hsu WS (2015). The study and application of multiaxial aircraft in military mission, *Army Bimonthly*. 51(541):131-151.

Li KY (2014). *Attitude control algorithm design-application of complementary filter*, Master thesis, Department of Aeronautical Engineering, Tamkang University New Taipei City.

Lin CY (2014). *Development of an attitude control system for quad-rotor UAV with fuzzy control*, Master thesis, Graduate Institute of Aeronautical and Electronic Technology, National Formosa University, Yunlin.

Liu CL (2015). *Attitude stabilization of a quad-rotor vehicle*, Master thesis, Department of Mechanical and Electro-Mechanical Engineering, Master thesis, Department of Aeronautical Engineering, Tamkang University, New Taipei City.

Pawlak ZZ (1982). Rough sets. J. Comput. Inf. Sci. 11(5): 41-356.

Qiu CY (2014). *The dynamic simulation of the quadrotor unmanned aerial vehicle*, Master thesis, Department of Aeronautical Engineering, Feng Chia University, Taichung.

Tai YJ (2013). *Attitude control of quadrotor using self-tuning fuzzy control method*, Master thesis, Department of Mechanical and Electro-Mechanical Engineering, National Yilan University, Yilan.

Wen KL (2008). *An introduction to rough set theory and application*, Wunan Publisher, Taipei.

Wen KL, Lee KLYT (2012). Applying rough set theory in the function group analysis for phenolic amide compounds, Comput. Electr. Eng. 38(1):11-18.

Wen KL, You ML (2017). *Apply soft computing in data mining,* Taiwan Kansei Information Association, Taichung.

Wiki (2017). Four-axis aircraft, from: https://zh.Wikipedia.org/wiki/%E5%9B%9B%E8%BD%B4%E9%A3%9E% E8%A1% 8C%E5% 99%A8,.

Yang JF (2010). *Attitude control of quadrotor*, Master thesis, Department of Aeronautics and Astronautics, National Cheng Kung University, Tainan,