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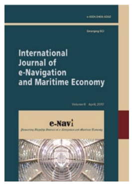


Original article

# Usability Evaluation Method of ECDIS Human-computer Interface Based on Emotional Experience

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**Abstract**

At present, ECDIS has been widely used in ship positioning, collision avoidance and navigation, and has developed into an important part of integrated navigation and automation system. However, most ECDIS software focuses too much on system function and technical level when realizing powerful navigation AIDS, neglecting the problems that the crew are most concerned about, such as realizing the human-computer interface operation quickly and simply as well as obtaining the information of human-computer interaction effectively and accurately. In order to improve the design of Electronic Chart Display and Information system（ECDIS） human-computer interface and its usability effectively, a new method for evaluating ECDIS human-computer interface is proposed. Starting from the concept and connotation of usability, five-factor personality model is used to measure the users' personality type in reference to the essence of usability (user's emotional experience) and calculate the basic emotional variant of users. Then, according to the users' emotional stimulation after finishing the given ECDIS task and combining with the system Usability scale (SUS), a tool dedicated to usability testing and five dimensions of usability evaluation proposed by Jakob Nielsen, father of usability, the emotion relationship model of usability and users is established by using partial least square method ( PLS ), and the validity of the model is verified with an aim to locate the key indicators that affect the usability of the ECDIS human-computer interface, It will be more helpful to improve the usability of ECDIS human-computer interface.

*Keywords: ECDIS human-computer Interface, Usability evaluation, Emotional experience, usability scale*



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## 1. Introduction

With the continuous development of ship navigation technology, the emergence of Electronic Chart Display and Information system (ECDIS), has led to a technological revolution in the field of navigation,and the research and application of nautical charts have entered a new era. The automation of navigation has been brought to a new level. At present, ECDIS has been widely used in ship positioning, collision avoidance and navigation, and has developed into an important part of integrated navigation and automation system. However, most ECDIS software focuses too much on system function and technical level when realizing powerful navigation AIDS, neglecting the problems that the crew are most concerned about, such as realizing the human-computer interface operation quickly and simply as well as obtaining the information of human-computer interaction effectively and accurately. The current ECDIS system hasmany functions and complex operations, so it is difficult for the crew to master. User-friendly ECDIS human-computer interface design is directly related tothe crew's cognitive efficiency to the system,and even to the safety of ship navigation (Li, 2009, p.3). For the development and application of ECDIS, International Maritime Organization (IMO) also puts forward that the development and application of ECDIS shouldbe theextensive, effective and timely interaction of navigation information as the goal, so as to improve the safety of navigation and protect the marine environment (Zhang, 2012, p.46). Asuccessful computer system can not be separated from a user-friendly human-computer interface, and a user-friendly human-computer interface can not be separated from the evaluation of the interface. Therefore, the evaluation of ECDIS human-computer interface becomes an urgent problem, and usability is one of the key indicators to measure human-computer interface.

## 2. Overview of usability

### *2.1. Concept of usability.*

In the 1940s, the United States began to study the usability of air force flight equipment. In the 1980s, researchers began to formally introduce the concept of "user usability" as a formal course in computer science. This symbolizes that people have begun to attach importance to the usability and user experience of the system (Chant, 2013, p.7). According to Jakob Nielsen (1994, p.3-5), father of usability, usability is defined in five dimensions, that is, learnability, efficiency, memorability, errors and satisfaction. ISO9241-11(2018, Part 11) also gives a definition about usability, which refers to the effectiveness, efficiency and user satisfaction of the product when the users make use of a product. The generalized concept of usability consists of the overall acceptability of the system and its subsystems, as is shown in figure 1 (Xiao, 2016, p.73). Usability in a narrow sense is whether the product is usable, easy to use, and whether the user can have a pleasant experience in using the product. Therefore, user-centered design has gradually become the trend of modern product design and development.

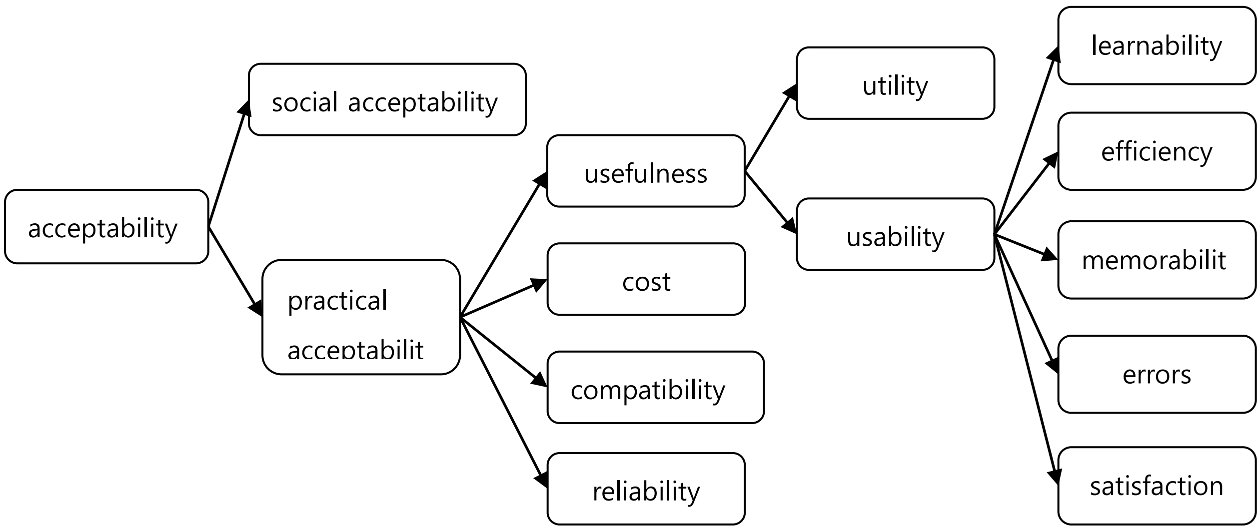


**Figure 1: Attribute model of system acceptability**

Source: Nielsen J., Usability engineering (1994), p.3-5.

### *2.2 Evaluation methods for usability*

In previous studies, the methods of human-computer interface usability evaluation mainly include expert evaluation, user model, user testing, cognitive traversal and user satisfaction survey etc. With the development of technology, researchers began to use eye movement tracking, facial expression recognition and other techniques to study usability evaluation. These above-mentioned methods can be more objective, qualitative and quantitative detection of problems. Howeve r, as the "user-centered" design concept continues to gain popularity, more consideration should be given t o emotional factors of user in assessing the usability of the product. Jeng.J. (2005, p.47) pointed out that in the process of using theproduct, the emotion of t he user will be affected by the level of product usab ility. The changes of the user's emotion can bemeas ured by measuring the physiological data such as El ectrocardiograph (ECG), electrodermal activity (EDA), electromyogram (EMG),which can reflect the product availability level indirectly. Lai Xiangwei (2007, p.3 1),from the users' experience of software use, propos ed the use of PAD emotional scale to obtain users' emotional state, and adopted neural networks to estab lish the relationship between user emotional changes and usability. Studies mentioned above show that mo st scholars use the pleasure-displeasure, arousal-nonar ousal and dominance-submissiveness (PAD) emotiona l scale tomeasure emotions and use the results asem otional indicator to help test product usability. Howe ver, PAD is not specifically designed for usability te sting. Therefore, a more professional assessment tool is needed so that further and quantitative research c an be done to better explain the relationbetween emo tions and product usability.

In summary, the emotional factors of users are paid more and more attention in usability research, and the subjective feeling of users is the criterion to judge the level of product usability. The emotional changes afte r the use of the product can best reflect the subjective feelings of the user. Therefore, it is a new direction to study the usability of products for us to pay attention to the change of users' emotion.This paper, taking the human-computer interface of ECDIS(NAVI-PILOT T1000), developed by our college as an exam ple, construct an emotional evaluation scale, obtain th e emotional data of users before and after using ECDI S through experiments, and establish a relationship m odel between ECDIS usability and users' emotional e xperience.The usability ofhuman-computer interface is measured by emotional experie nce.

## 3. Research methods

Through the users' emotion calculation and evaluation, the emotion vector *Eu* generated by the usability level of ECDIS is calculated, and the usability data is obtained by the tools specially used to test the usability. the relationship model between usability and user emotion is established together with the user emotional data. Then the model is analyzed and validated to evaluate the usability level of ECDIS human-computer interface.

### 3.1. Users' emotion calculation and evaluation

#### 3.1.1. Emotion vector model

The occurrence of any emotion is stimulated by the external force. Every user's emotion has an initial state before using a product, and after using the product, the user's emotion will have a certain change. After using ECDIS software, the users will have a total emotional experience, which is gradually generated based on the initial state of the user emotion. The user emotion we studied consists of the intrinsic component of the user's own personality and the emotional changes caused by the usability level after the use of ECDIS software. The intrinsic emotional component of the user's personality does not change during the use of ECDIS. Then the emotional vector *Eu* generated by the ECDIS usability level is the difference between the total amount of emotion *E* when completing a given task and the initial emotion vector $E_0$ , and the relationship model is $Eu=E-E_0$. The total amount of emotion *E* when the user completes a given task can be obtained by establishing the user's total emotional evaluation scale. The initial emotional vector $E_0$ of the user needs to be calculated through the conversion of personality, sentiment and emotion.

#### 3.1.2. Conversion relationship among personality, feeling and emotion

The calculation of user's initial emotion vector $E_0$ needs to transform from one user's personality space to his feeling space, and then from user's feeling space to user's emotion.

*(a)Conversion between Personality Space and emotional Space*

Five Factor Personality Model is used to determine the user's Personality Space (FFM). Five factors includes Openess, Conscientiousness, Extraversion, Agreeableness and Neuroticism(Wiggins, 1996, p.55). The personality vector $P=(P_1, P_2, P_3, P_4, P_5)^T$,$P_i \in [0, 1]$,$i$=1, 2, 3, 4, 5.

In the monitoring process of users' feeling space, we mainly use the PAD feeling space model proposed by Mehrabian (1995, p.339).The PAD feeling space model is composed of three related emotional dimensions: *P* means pleasure-displeasure;*A* means arousal-nonarousal; *D* stands for dominance-submissivenesse. Among them, the *P* is mainly used to distinguish the positive and negative emotional intensity of the user; *A* is mainly used to distinguish the physical activity degree and the mental tension degree of the user and *D* is mainly used to distinguish the subjective activity intensity of the user. These three dimensions constitute the emotion space vector *M*, $M=[m_P, m_A, m_D]$T, $-1 \leqq m_P, m_A, m_D \leqq 1$,among which, M=[0, 0, 0]T is the mood in a calm state. The conversion formula of user personality space vector to user feeling space vector is as follows (Patrick, Gebhard, 2005):

$$M = K * P \qquad (1)$$

$$K = \begin{bmatrix} 0 & 0 & 0.21 & 0.59 & 0.19 \\ 0.15 & 0 & 0 & 0.30 & -0.57 \\ 0.25 & 0.17 & 0.60 & -0.32 & 0 \end{bmatrix}$$

Among them, matrix $K$ is the transformation matrix of personality and mood.

*(b)Among which, Conversion between feeling and emotion space*

The mapping relationship between feeling and emotional space is defined as:

$$E = f(M, PAD^*) = D / \sum_{i=1}^{24} d_i \qquad (2)$$

Among which:$D=[d_1, d_2, d_3, ..., d_{24}]$; $d_i = [(M - PAD_i)^T (M - PAD_i)]^{1/2}$, $i=1, 2, 3, ..., 24$;$PAD^*$ is the mapping base of the OCC emotion model (Ortony, Clore and Colins constructed a cognitive theory of emotion, OCC) in PAD feeling space. The advantage of this model is that it can do a good corresponding with the OCC feeling model, which is the dominant in psychology and engineering circles. Patrick Gebhard (2005, p.10) has given the corresponding relation table of the two models. In the OCC model, the feeling is classified into 24 categories (Table 1).

**Table 1:PAD projection table of OCC feeling space model**

| Emotion | P | A | D | Mood Octant |
|---|---|---|---|---|
| Admiration | 0.5 | 0.3 | -0.2 | +P+A-D Dependent |
| Aanger | -0.5 | 0.59 | 0.25 | -P+A+D Hostile |
| Disliking | -0.4 | 0.2 | 0.1 | -P+A+D Hostile |
| Disappointment | -0.3 | 0.1 | -0.4 | -P+A-D Anxious |
| Distress | -0.4 | -0.2 | -0.5 | -P-A-D Bored |
| Fear | -0.6 | 0.6 | -0.43 | -P+A-D Anxious |
| Fears Confirmed | -0.5 | -0.3 | -0.7 | -P-A-D Bored |
| Gloating | 0.3 | -0.3 | -0.1 | +P-A-D Docile |
| Gratification | 0.6 | 0.5 | 0.4 | +P+A+D Exuberant |
| Gratitude | 0.4 | 0.2 | -0.3 | +P+A-D Dependent |
| Happy For | 0.4 | 0.2 | 0.2 | +P+A+D Exuberant |
| Hate | -0.6 | 0.6 | 0.3 | -P+A+D Hostile |
| Hope | 0.2 | 0.6 | 0.3 | +P+A-D Dependent |
| Joy | 0.4 | 0.2 | 0.1 | +P+A+D Exuberant |
| Liking | 0.4 | 0.16 | -0.24 | +P+A-D Dependent |
| Love | 0.3 | 0.1 | 0.2 | +P+A+D Exuberant |
| Pity | -0.4 | -0.2 | -0.5 | -P-A-D Bored |
| Pride | 0.4 | 0.3 | 0.3 | +P+A+D Exuberant |
| Relief | 0.2 | -0.3 | 0.4 | +P-A+D Relaxed |
| Remorse | -0.3 | 0.1 | -0.6 | -P+A-D Anxious |
| Reproach | -0.3 | -0.1 | 0.4 | -P-A+D Disdainful |
| Resentment | -0.2 | -0.3 | -0.2 | -P-A-D Bored |
| Satisfaction | 0.3 | -0.2 | 0.4 | +P-A+D Relaxed |
| Shame | -0.3 | 0.1 | -0.6 | -P+A-D Anxious |

Source:Patrick Gebhard, ALMA一A Layered Model of Affect (2005), p. 25-29 .

The PAD * is a 3 *24 matrix, in which each column *PADi(i=1,2,…,24)* corresponds to the mapping vector of the basic dimension of emotion in the PAD emotional space in a OCC emotional model. The $E_0$ is calculated by formula 1 and 2 ,that is the basic emotion vector of the user.

### *3.1.3. Establishment of general emotional evaluation scale*

Xu Na (2013, p.30)and others collected 294 common affective words by means of perceptual engineering in the research on the usability of network software, and then consulted professionals and investigated 40 college students to find out the reliability and validity of these emotional words. In the analysis, 14 groups of emotional word pairs were determined after eliminating redundant and invalid items, and the user emotion evaluation scale was established.The emotional evaluation scale adopted in this paper draws on the research results of Xu Na and others. We interviewed 20 captains of class A with rich maritime experience and conducted a questionnaire survey on them. We selected and supplemented from these 14 groups of emotional words and finally 10 sets of emotional word pairs were determined (see Table 2). The scale of emotional evaluation was quantified with the scale of grade 11 （-5, -4, -3, -2, -1, 0, 1, 2, 3, 4, 5）.

**Table 2:Emotional word pairs**

| No. | Emotional words | No. | Emotional words |
|---|---|---|---|
| $E_1$ | Being guided-autonomous | $E_6$ | painful-pleased |
| $E_2$ | confused-clear | $E_7$ | bored-enjoyable |
| $E_3$ | regrettable-satisfied | $E_8$ | worried-confident |
| $E_4$ | disappointed-surprised | $E_9$ | depressed-inspired |
| $E_5$ | distracted-committed | $E_{10}$ | Upset-quiet |

Source:Xu, Na., A Usability Evaluating Method for Website Based on Users' Affective Experience(2013), p. 30-35.

### *3.2. Usability testing tools*

The tool used in the usability testing software of the ECDIS human-computer interface is the system Usability scale (SUS) put forward by Robert Bentley and John Brooke (2013), which was used for the software usability evaluation. The reliability of the system usability scale is very high, which is above 0.85. The reliability can reach up to 0.92 in the case of 324 samples. The advantage of SUS in small samples is more obvious than that in QUIS(Questionnaire for User Interface Satisfaction, QUIS) and CSUQ (Computer System Usability Questionnaire, CSUQ). Data based on t-test of random sub-samples of various sizes.Twenty subsamples were taken at each sample size for eachsite and each questionnaire.What is plotted is the percentage of those 20 tests that yielded the same conclusion as the analysis of the full dataset (that site 1 was significantly preferred over site 2). see figure 2.

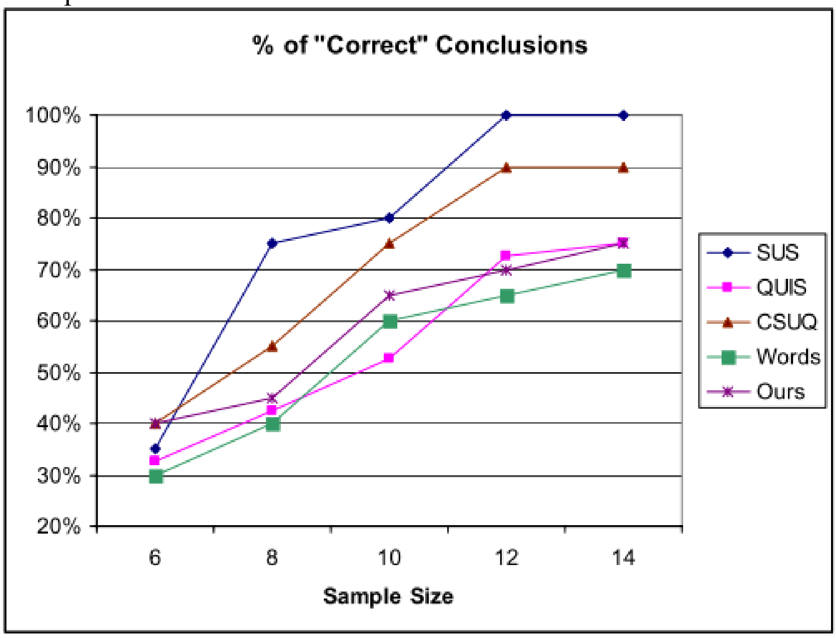


**Figure2:The reliability of diffirent tool used in the usability testing software**

Source: http://www.csdn.net/.

### 3.2.1. Test methods

According to the five dimensions of usability evaluation proposed by Jakob Nielsen ( Learnability, Efficiency, Memorability, Errors, and Satisfaction ) , the SUS questionnaire is designed in this paper. (see Table 3, the questionnaire requires users to give their consent to the single index of each dimension, with a score of 5 levels, with a minimum score of 1 and a maximum of 5 points. Then the availability evaluation value of each dimension is obtained according to the calculation.

**Table 3：SUS questionnaire**

| Learnability | | 1 | 2 | 3 | 4 | 5 | |
|---|---|---|---|---|---|---|---|
| It is very easy for me to learn to use | completely disagree | ○ | ○ | ○ | ○ | ○ | completely agree |
| I can master it well in a short time | completely disagree | ○ | ○ | ○ | ○ | ○ | completely agree |
| Efficiency | | 1 | 2 | 3 | 4 | 5 | |
| It makes my job more efficient | completely disagree | ○ | ○ | ○ | ○ | ○ | completely agree |
| It is useful to me | completely disagree | ○ | ○ | ○ | ○ | ○ | completely agree |
| It can be time-efficient to use | completely disagree | ○ | ○ | ○ | ○ | ○ | completely agree |
| Memorability | | 1 | 2 | 3 | 4 | 5 | |
| I can easily remember how to use | completely disagree | ○ | ○ | ○ | ○ | ○ | completely agree |
| It is easier to use next time | completely disagree | ○ | ○ | ○ | ○ | ○ | completely agree |
| Errors | | 1 | 2 | 3 | 4 | 5 | |
| I promise I will not make mistakes when use | completely disagree | ○ | ○ | ○ | ○ | ○ | completely agree |
| It will be serious if any mistakes occur | completely disagree | ○ | ○ | ○ | ○ | ○ | completely agree |
| Satisfaction | | 1 | 2 | 3 | 4 | 5 | |
| I am very satisfied | completely disagree | ○ | ○ | ○ | ○ | ○ | completely agree |
| It looks so beautiful | completely disagree | ○ | ○ | ○ | ○ | ○ | completely agree |
| I am pleased to use | completely disagree | ○ | ○ | ○ | ○ | ○ | completely agree |

### 3.2.2. Dimension usability evaluation model

Each dimension can calculate the contribution weight of a single indicator to user satisfaction,here it is called the importance coefficient *Ir*. The calculations are as follows:

$$I_r = \overline{c_r} / \sum_{i=1}^{m} \overline{c_i} \qquad (3)$$

In which:*r* is the corresponding series number of a dimension, *r=1, 2, 3…m*; *m* is the corresponding indicator of a dimension;

$\overline{c_i}$ :the average score of indicator "*i*"; $\overline{c_r}$ :the average score of indicator "*r*";

$I_r$ :the importance coefficient of indicator "*r*",*r=1, 2, 3… m*;

Its usability evaluation value can be obtained by converting the average score of each indicator based on the following formula:

$$U_r = (\overline{C_r} - 1) * I_r * 5 \qquad (4)$$

*Ur*:usability evaluation value of the indicator "*r*"

The usability assessment for each dimension can be concluded:

$$D_i = \sum_{r=1}^{m} U_r \qquad (5)$$

*Di*:usability evaluation value of the indicator "*i*"

The global usability evaluation value "*H*":

$$H = \sum_{r=1}^{5} D_i \qquad (6)$$

$H$: global usability evaluation value

After the experiment, the user was asked to fill in the questionnaire to evaluate the usability of the ECDIS human-computer interface, and the usability data and the user emotion data were used to establish the usability and emotional relationship model.

## 4. An example of usability evaluation of ecdis human-computer interface

### *4.1.Experiment process*

*(a) Experimental software*

The experimental software ECDIS (NAVI-PILOT T 1000) is developed by our college and it conforms to IMO standard (figure 3).

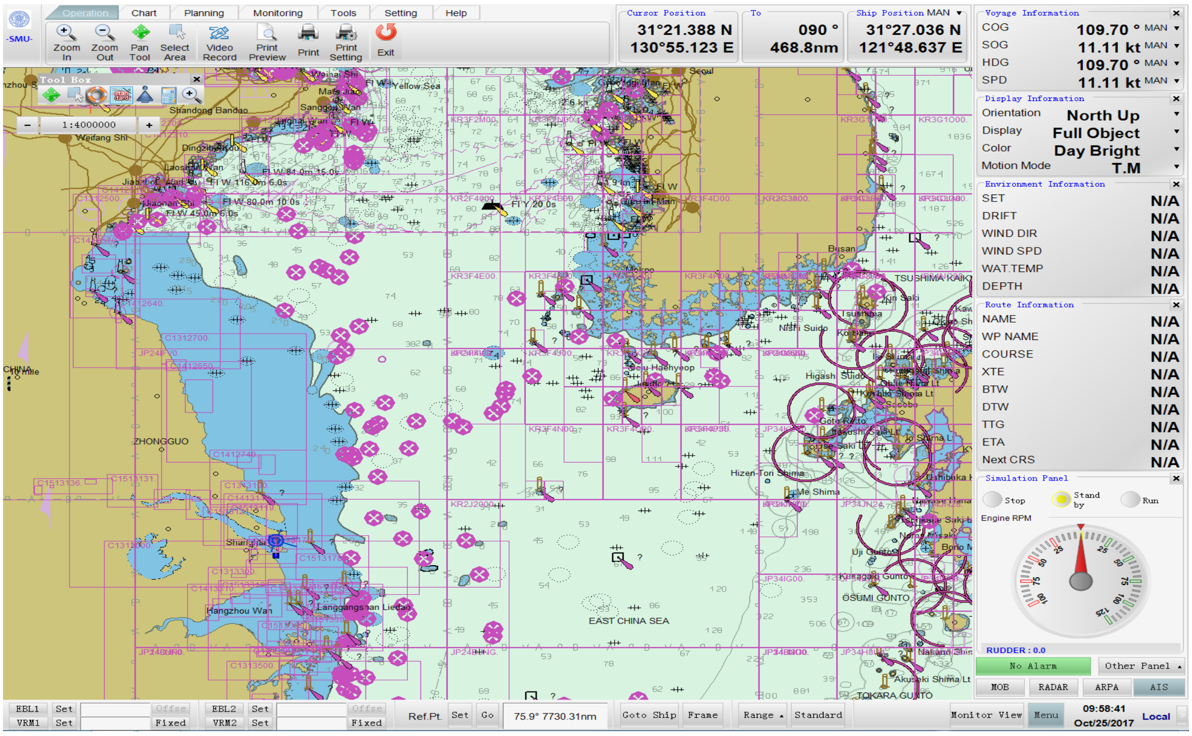


**Figure 3: ECDIS Human-Computer Interface**

*(b) Experiment purpose*

This paper tests the emotional change data of different users before and after they perform typical tasks in ECDIS, establishes the relationship model of the two and evaluates the usability of ECDIS human-computer interface by combining the tools specially used for usability testing.

*(c) Trial user selection*

According to the Nielsen (1994, p.5) study, in usability testing, there is a certain relationship between the usability problem discovery rate and the number of participants in the usability test, which can be described as: $P(n \geqq 1) = 1 - (1-P)^n$

In which, $P$ refers to the estimated value of the discovery rate, n stands for the number of participants in the test.

In general, the P value is 0. 31. According to the further study and calibration of $P$ value by Hartson (1998, p.103), it is concluded that for commercial application software, the P value is 0.37; for software used by consumers, the P value is 0.23; For websites, the P value is 0. 040. Therefore, we selected 15 graduate students majoring in navigation technology as the subjects. But none of them have ever used the software and can be considered as the new user in usability research.

*(d) Experiment task*

According to the use of ECDIS function, specify the typical task of the experiment. Experimental tasks should cover the main areas of ECDI operation, as shown in the table 4.

**Table 4: ECDIS operation task**

| Task | Task description |
|---|---|
| 1 | Open ECDIS system and check the sensor siganal |
| 2 | Select chart scale to enlarge |
| 3 | Select the chart scale to reduce |
| 4 | Mode switching during daytime and Night |
| 5 | Add a route with 5 way points |
| 6 | Measure the bearing and ranging between any two positions |
| 7 | Move the chart |
| 8 | Query the chart information in the current interface |
| 9 | Exit the system from the menu bar |

*(e) Experiment process*

The usability evaluation experiment of ECDIS human-computer interface consists of four stages: pre-experiment preparation, experiment task design, experiment implementation and experiment data analysis, and the detailed flow map is shown in figure 4.

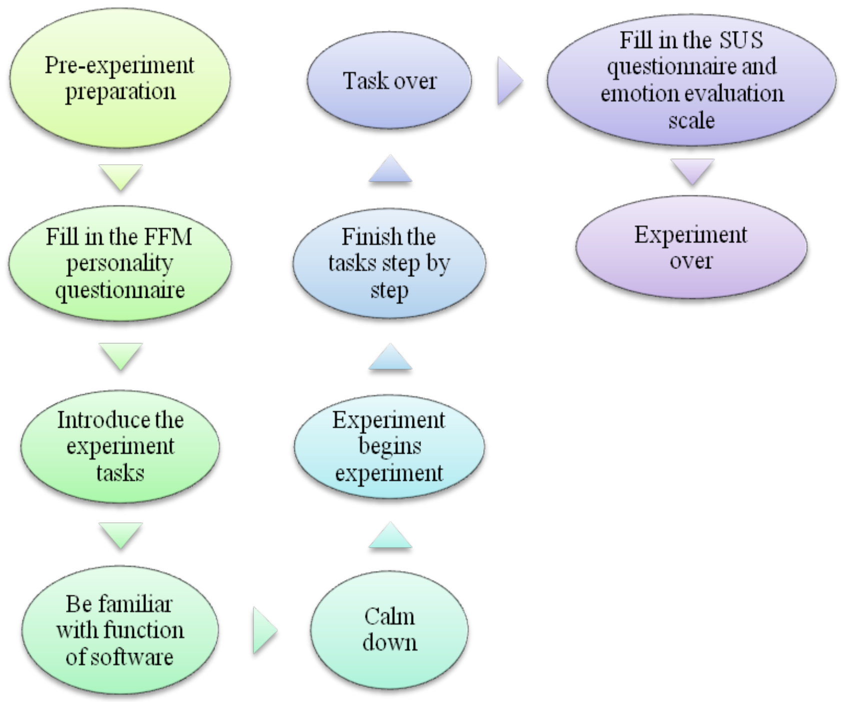


**Figure 4: Experiment flow map**

*4.2 . Data analysis and processing*

At the end of the experiment, the original scores of FFM personality survey of 15 subjects were counted and converted into standard scores, and then the data of emotional evaluation scale was reduced to [-1,1] range (Babcock, and Lipps., 2002. Lin, et al. 2003). Because the setting of emotion category in the emotion model in this paper is not completely consistent with the OCC model, the initial value of emotional personality component is *0* for the OCC emotion category that is not in the emotional assessment scale. According to the research ideas of 3.1, the user emotional value caused by ECDIS usability is calculated by data processing $E_i$ ( i=1, 2, …,10 ) . The scores of SUS questionnaire were statistically analyzed and the availability values of 5 dimensions and global usability were calculated by using the data of SUS usability questionnaire of 15 subjects, which were sorted out in Table 5.

**Table 5:Emotional values cause by ECDIS usability**

| types / tested | $V_1$ | $V_2$ | $V_3$ | $V_4$ | $V_5$ | $V_6$ | $V_7$ | $V_8$ | $V_9$ | $V_{10}$ |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.8 | 0.2 | -0.42 | 0.6 | -0.65 | 0.18 | 0.94 | -0.44 | 0.13 | 0.2 |
| 2 | 0.6 | 0.4 | -0.42 | 0.2 | -1.05 | 0.38 | 0.54 | -0.44 | -0.27 | 0.2 |
| 3 | -0.2 | 0.4 | 0.18 | 0.8 | -0.65 | -0.02 | 0.34 | 0.76 | 0.53 | -0.4 |
| 4 | 0.4 | -0.2 | -0.62 | 0.2 | -0.25 | 0.18 | 0.74 | -1.04 | -0.67 | 0.6 |
| 5 | 0.4 | 0 | -0.42 | 0.8 | -0.45 | -0.22 | 0.14 | 0.56 | -0.47 | -0.2 |
| 6 | 0 | 0.6 | -0.02 | 1 | -0.85 | -0.22 | 0.34 | -0.84 | 0.73 | -0.4 |
| 7 | 0.6 | -0.4 | -0.82 | 0.6 | -0.45 | -0.22 | 0.54 | -0.44 | 0.93 | 0.6 |
| 8 | -0.2 | -0.2 | 0.38 | 0.2 | -0.25 | -0.02 | -0.06 | -0.04 | 0.93 | 0.8 |
| 9 | 0.4 | -0.2 | -0.42 | 0.4 | -0.65 | -0.02 | 0.54 | 0.96 | -1.07 | 1 |
| 10 | 0.6 | 0.2 | -0.82 | 0.6 | -0.45 | -0.22 | 0.94 | 0.36 | -0.67 | -0.8 |
| 11 | 0.4 | 0.6 | -0.42 | 0.8 | -0.65 | 0.38 | 0.54 | 0.56 | -0.07 | -0.6 |
| 12 | 0 | 0.4 | -0.22 | 1 | -0.85 | 0.18 | 0.34 | -0.64 | 0.53 | 0.6 |
| 13 | 0.6 | 0.6 | -0.62 | 0 | -1.05 | -0.42 | 0.14 | -0.84 | 0.13 | -0.4 |
| 14 | 0.8 | -0.2 | -0.82 | 0.8 | -0.65 | 0.18 | -0.26 | -0.64 | -0.47 | -0.2 |
| 15 | 0.2 | 0.4 | 0.38 | 1 | -1.05 | -0.22 | -0.26 | -0.84 | 0.13 | 0.6 |

**Table 6 :Test data of SUS of 15 participants**

| tested | Learnability | Efficiency | Memorability | Errors | Satisfaction | Global |
|---|---|---|---|---|---|---|
| 1 | 13 | 16 | 15 | 16 | 16 | 76 |
| 2 | 13 | 17 | 16 | 15 | 15 | 76 |
| 3 | 14 | 15 | 15 | 15 | 15 | 74 |
| 4 | 13 | 16 | 17 | 13 | 16 | 75 |
| 5 | 15 | 17 | 15 | 17 | 18 | 82 |
| 6 | 12 | 17 | 14 | 16 | 18 | 77 |
| 7 | 14 | 18 | 15 | 18 | 17 | 82 |
| 8 | 13 | 16 | 16 | 15 | 16 | 76 |
| 9 | 16 | 18 | 15 | 18 | 17 | 84 |
| 10 | 13 | 15 | 17 | 16 | 16 | 77 |
| 11 | 14 | 16 | 16 | 18 | 16 | 80 |
| 12 | 17 | 19 | 18 | 18 | 18 | 90 |
| 13 | 16 | 17 | 16 | 16 | 16 | 81 |
| 14 | 15 | 15 | 16 | 14 | 17 | 77 |
| 15 | 14 | 15 | 16 | 15 | 16 | 76 |

## 5. Relation model between users' emotion and ecdis usability

### 5.1. Modeling and analysis

The correlation analysis of user emotion data and usability data in Table 5 and Table 6 are carried out and it shows that there is a strong correlation between independent variables. When there is strong correlation between independent variables, partial least square method (PLS) can consider the relationship between multiple independent variables and dependent variables, and complete the regression modeling of multiple independent variables and multiple dependent variables (Meng, et al. 2019, P.201). Moreover,it combines the characteristics of canonical correlation analysis, linear regression analysis and principal component analysis. It can output accurate relationship model quickly and easily, and can help to understand the model more deeply. Therefore, according to the data of 15 subjects, the number of main components r is 4. We select PLS method to establish the relationship model between

$$I=C_i+K_1*V_1+K_2*V_2+K_3*V_3+K_4*V_4+K_5*V_5+K_6*V_6+K_7*V_7+K_8*V_8+K_9*V_9+K_{10}*V_{10}=C_i+\sum(K_i*E_i) \quad (7)$$

$I$ refers to five dimensions of usability evaluation and one Global.

$C_i$ refers to The constant of the fitting model,i=1, 2, 3, ...10

usability value and user emotion as follows:

$K_i$ is emotion variable coefficient,$V_i$ is emotion variable i=1, 2, 3, ...10.

Calculate the usability index value and emotional variable value by pycharm software as shown in Table 7.

**Table 7:usability index and emotional variable values**

| Ki,Ci \ I | Learnability | Efficiency | Memorability | Errors | Satisfaction | Global |
|---|---|---|---|---|---|---|
| $K_1$ | -1.2556 | -2.1635 | -1.2776 | 1.5414 | -1.9156 | -4.0711 |
| $K_2$ | 5.8193 | 3.5246 | 3.7334 | 7.7502 | 2.4911 | 23.3187 |
| $K_3$ | -5.6781 | -4.8448 | -2.4285 | -4.9443 | -2.8410 | -20.7368 |
| $K_4$ | 0.6150 | 0.3174 | -0.0696 | 1.9242 | 2.0381 | 4.8251 |
| $K_5$ | -1.9890 | 2.0653 | 3.0568 | 3.6088 | 2.1701 | 10.7025 |
| $K_6$ | -0.9890 | -0.7915 | 0.8148 | -2.0528 | -1.4424 | -4.4608 |
| $K_7$ | -1.4515 | -0.4979 | -1.2134 | -1.3880 | -1.1666 | -7.7175 |
| $K_8$ | 1.33438 | 0.7298 | -0.3854 | 2.3728 | 0.0322 | 4.0932 |
| $K_9$ | 0.0497 | 0.7595 | -0.4976 | 1.5259 | -0.0359 | 1.8015 |
| $K_{10}$ | 3.3464 | 2.9093 | 1.3699 | 4.1035 | 1.5520 | 13.2812 |
| $C_i$ | 13.6416 | 14.8354 | 17.0953 | 14.1565 | 15.875 | 75.6041 |

### *5.2. Model validation*

In order to verify the validity of the model, three experiments were carried out, and the data of three users were added to the PLS model. The predicted value is calculated and the error is the difference between the actual value and the predicted value .The predicted values of the model and the usability index values measured by the SUS questionnaire are shown in Table 8. Table 8 comparison of measured availability index values with model prediction values in SUS questionnaire.

**Table 8:Comparison of measured usability values in SUS questionnaire and model predicted values**

| Usability index | USER No.1 | | | USER No.3 | | | USER No.3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Actual value | Predicted value | Error | Actual value | Predicted value | Error | Actual value | Predicted value | Error |
| Learnability | 15 | 15.1322 | -0.1322 | 13 | 13.9836 | -0.9836 | 14 | 14.3461 | -0.3461 |
| Efficiency | 18 | 17.9549 | 0.0451 | 17 | 16.3824 | 0.6179 | 16 | 16.0243 | -0.0243 |
| Memorability | 18 | 18.3328 | -0.3328 | 18 | 17.9586 | 0.0416 | 17 | 17.6435 | -0.06435 |
| Errors | 16 | 16.2456 | -0.2456 | 15 | 15.8467 | -0.8467 | 15 | 15.9462 | -0.9462 |
| Satisfaction | 17 | 17.5196 | -0.5196 | 17 | 16.2491 | 0.7509 | 16 | 15.7153 | 0.2847 |
| Global | 78 | 79.1432 | -1.1432 | 77 | 75.9546 | 1.0454 | 76 | 78.0438 | -2.0438 |

From the results of error calculation in Table 8, it can be seen that there is no significant difference between the actual value of availability index and the predicted value. It shows that the model can accurately predict the availability index value and the validity of PLS model can be guaranteed (Liu, 2019, P.125, Tatsuro, 2019, P.233, Xiong, 2019, P.115).

## 6. Conclusion

Table 7 shows that among the 10 emotional variables, the 5 variables including $E_1$, $E_2$, $E_3$, $E_5$ and $E_{10}$ have a strong ability to interpret dependent variables, which indicates that these 5 emotional variables are important indicators to evaluate the usability of ECDIS software. The effect of $E_2$, $E_5$ and $E_{10}$ in the 5 emotional variables is positive, indicating that the greater the value of these three variables is, the better the usability of ECDIS software is. The influence of $E_1$ and $E_3$ is negative, which can be explained as: the greater the value of $E_1$ is, the greater the autonomy of the users is. Software is used mainly by the user to grope, rather than to provide effective guidance and advice to the user, which reflects the existing problems in the ECDIS human-computer interface.The higher value of $E_3$ indicates that the software does not meet the requirements of the users well with a lower usability level.Several other independent variables have the same ability to interpret dependent variables in each model, and the larger the value is, the higher the level of usability of ECDIS software is.

Starting from the essence of usability (user emotional experience) and based on the idea of perceptual engineering research, this paper explores a method to evaluate the usability of ECDIS human-computer interface by using user emotional experience. Through the user emotion calculation and evaluation and in combination with the usability data obtained by the tools specially used to test usability, and the relationship model between the usability and user emotion is established together with the user emotion data, and then the model is analyzed and verified to evaluate the level of usability of ECDIS human-computer interface. The shortcoming of this paper is that the user emotion evaluation belongs to subjective evaluation, and in the future research, we can use the physiological data such as eye movement instrument and EEG to evaluate the usability level of ECDIS, which will be more helpful to improve the usability of ECDIS human-computer interface.

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