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Design of User Interface for Tractor Cab Real-time Information Management System

Weiwei ZHOU[1,2], Yang LU[1], Chunxia JIANG[1], Zhixiong LU[1*], Wenxin JIN[3]

1. College of Engineering, Nanjing Agricultural University, Nanjing 210031, China; 2. Yangzhou Polytechnic Institute, Yangzhou 225127, China; 3. Department of Mechanical and Electrical Engineering, Jiangsu Polytechnic College of Agriculture and Forestry, Jurong 212400, China

Abstract In this paper, the user interface of tractor cab real-time information management system was designed. Based on the principle of "user friendly", it reasonably arranged spatial position of information management system according to spatial distribution of tractor cab. Then, it analyzed operation habits and thinking ways of drivers, and formulated design principle meeting demands of drivers. Besides, it used LabView software to design user interface, including interface layout and interface design. User interface includes basic information interface, job information interface, camera monitoring interface, and fault diagnosis interface. Finally, it made evaluation of the user interface from color, indicator lamp, dial, and pointer. Results indicate that the designed user interface layout conforms to cognition mentality and operation habits and easy to get familiar and grasp; graphical interface is vivid and easy to stimulate pleasure of drivers in operation; interface color matching is coordinated; the layout of controls is hierarchical and logic, and operating mode is consistent with Windows system.

Key words Tractor, Information management system, User interface, LabView

Virtual instrument is a great breakthrough in concept and functions of traditional instruments. Using graphical soft panel established on computer screen, virtual instrument can conveniently realize various functions. In essence, soft panel is man machine interface and is the medium for man and machine transmitting and exchanging information. After entry into information society, the man machine interface is gradually changing to user interface technology[1-3]. Design quality of user interface directly influences operation performance and competitive power of virtual instruments. With development of microcomputer control technology and virtual instrument technology, electronic and intelligent degree of agricultural machinery is gradually improving, and the application of virtual instrument in tractors has become an inevitable development trend. Using graphical programming tool LabView, on the basis of user friendly design idea, we selected proper interaction method and scientifically divided man machine task, developed simple, high efficient, friendly, and easy tractor cab real-time information management system (hereafter referred to as information management system), and made evaluation of user friendly interface, to provide reference for related researches.

1 Spatial layout of the real-time information management system

Tractor cab is the place for driver obtaining information and making correct and safe driving. In the cab, there are many instruments and operating levers. Only through conforming to visual characteristics and placing in normal field of vision of driver, may the information management system obtain information rapidly, accurately, safely and reliably[4]. Ergonomics determines optimum range of field of vision in horizontal and perpendicular planes, *i.e.* horizontal direction[$-15°$, $15°$], perpendicular direction[$0°$, $30°$], and natural rotation angle of horizontal direction $45°$[5]. "User friendly" design idea requires that the layout of information management system in tractor cab can make the driver efficiently and quickly obtain the most important driving information in most comfortable state. After surveying and analyzing operating habits of drivers, combining spatial distribution of cab, we used eyellipse locating method to determine driver's field of vision[6]. Besides, according to methods in references[4], we firstly determined dimension of operating console in driver cab and then established the optimum spatial distribution of information management system.

2 Design principles of user interface

The information management system provides operating parameters, working status and fault information for driver, so it is an indispensible part of tractor. With rapid development of control technology and urgent demand for accelerating agricultural modernization, users have higher and higher requirements for tractor displaying driving and operating information, such as visual, clear, stable, rapid, and accurate. Taking conforming to operating habits of tractor drivers and facilitating users as ultimate purpose, in line with adverse hostile and complex working environment, we proposed following basic principles for design of information management system.

(i) Visual and clear interface. The information management system needs displaying miscellaneous information and operating environment is complicated. Thus, the information management system should display visual and brief information, and operation

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* Corresponding author. E-mail: luzx@njau.edu.cn

shall be convenient, make drivers understand at a glance, and rapidly and accurately grasp important information of tractor, including tractor speed, engine speed, cooling water temperature, oil pressure, residual fuel, distance traveled, working area, time, and date, etc.

(ii) Real time. Since working environment of tractor is extraordinarily complicated, the specific information display shall be in real time. Any delay of information acquisition may cause drivers to fail to effectively control tractor normally, safely and efficiently, such as lamp and alarming signals, including left and right steering lamps, high beam, battery voltage alarm lamp, inlet gas pressure alarm lamp, and neutral indicator lamp. Besides, fuel consumption, plowing depth, harrowing depth, real-time sowing amount, real-time irrigation amount, pressure of compressor pump should satisfy real-time. Otherwise, it may lead to error of miss cultivation, miss plowing, and miss sowing, influencing operating efficiency of tractor, and resulting in waste of resources. Therefore, display of such information must be refreshed periodically at high frequency with changes of real-time data, to reflect actual conditions of tractor operation in real time.

(iii) Rich information. With constantly strengthening of operating functions of operating devices and tools carried by tractor, drivers demand more and more information from information management system. Drivers need promptly and accurately know driving condition of tractor, including driving speed, engine speed, and cooling water temperature, and driving wheel slide rate. Besides, they need know working conditions and efficiency of operating devices and tools, such as normal working, operating width, plowing depth, harrowing depth, sowing amount, fertilizer application amount, pesticide spraying amount, harvesting amount, fuel consumption, residual fuel, real-time operating area, unit time operating area, total operating area, real-time operating time, total operating time, real-time driving distance, total and unit time operating area, unit time fuel consumption, and unit operating area. To meet habits of farmers, unit operating area is calculated at mu or hectare (one mu is equal to about 667 m2). Through such information, drivers can control normal work of tractor in an effective way, adjust its working status, and increase its working efficiency.

(iv) Quick reaction. This is requirement for design of interface software. If the information management system fails to respond promptly, it will lead to delay of important command[7]. Apart from absolute duration of response time, the difference in response time of system to different operation commands is also very important. If the difference is excessive, it will directly influence user experience of driver in system operation, reduce pleasure in operation, or even lead to antagonistic psychology of driver.

(v) Stable and reliable, anti-interference. This is also requirement for design of interface software. Working environment of tractor is hostile, and high power tractor is widely used. To increase working efficiency and ensure safe work and avoid traffic accident, the information management system shall be reliable and anti-interference. Otherwise, if driver receives unreliable information, it may lead to wrong operation and lead to operation accident. This will not only reduce working efficiency of tractor, lead to property loss, but also threaten life safety of driver. In addition, information reliability is also requirement for fine farming of modern agriculture.

3 Interface layout and design

Information management system is a man-machine system. Information exchange and control activities between driver and system happen on user interface. Therefore, design quality of interface determines accessibility of this system and operation and control ability of driver over this system. In the design of the user interface, taking driver as center, we analyzed operation habits of driver, made survey and analysis of user experience, studied demand of driver for different information, and judge the importance degree of different information. It is recommended to reasonably and scientifically divide information according to importance degree, and display in different indication areas, to make the system conform to operation habits of driver to the maximum extent, to make driver rapidly and accurately exchange with the system, learn and grasp all functions of the system in the shortest time, and to increase working efficiency, build self-confidence, stimulate creativity, and bring sense of achievement.

We used graphical programming tool LabView to design the information management system. As virtual instrument test platform, LabView is a highly flexible G language based development system[8-14]. G language is a general graphical programming language oriented towards objects and having extended function library. The program of G language is called virtual instrument (VI), because its interface and function are quite like real instrument. All applications developed in LabView environment are suffixed with VI to reflect the meaning of virtual instrument.

A VI consists of interactive user interface, data flow block diagram, and icon terminal. The front panel is interactive user interface of VI. Similar to real physical instrument panel, it includes button, dial, switch, diagram and other interface tools. User can obtain data display results from keyboard and mouse. The data flow block diagram is a graphical method for programming and it is in fact program code of VI. Icon terminal is like a graphical parameter list and can transmit data between VI and sub VI[13]. Now, LabView is widely applied in measurement, control, teaching, and scientific research fields. Inbuilt with many practical functions, it can conveniently perform data acquisition analysis display, instrument control, measurement test, and industrial process simulation and control, and it is highly extensible[14].

3.1 Interface layout Interface layout refers to position, size and spacing of display area, icon and controls and the coordination and balance of these three points[15]. After fully considering functions to be realized and analyzing specialized knowledge of tractor application fields and operation habits of drivers, we made scientific and reasonable area division of system interface, as shown in

Fig. 1 and Fig. 2. In Fig. 1, the user interface includes three parts: task bar, lamp and alarming area, and main display area. The length of left task bar is same as height of bottom lamp and alarming area. The ratio of task bar height to length of lamp and alarming area is 1.0:1.5; the ratio of main display area to height of lamp and alarming area is 5:1; the ratio of area of task bar, lamp and alarming area, and main display area is 1.0:1.5:7.5. When tractor performs different jobs, the display information will be varied. According to this, the main display area is further divided into three parts: option field, fixed information and change information, and the ratio of area is 1.0:1.5:6.0. As shown in Fig. 2, option field and fixed information are located in left and right side of main display area, and change information is located in the center.

3.1.1 Task bar. In the task bar, there are such icons available as tractor operation information, camera monitoring, fault and diagnosis (as shown in Fig. 3). Selecting tractor information icon (Fig. 3 – A), it changes current interface to tractor operation information interface; selecting camera monitoring icon (Fig. 3 – B), it changes to camera monitoring interface; selecting fault and diagnosis icon (Fig. 3 – C), it changes to fault diagnosis interface.

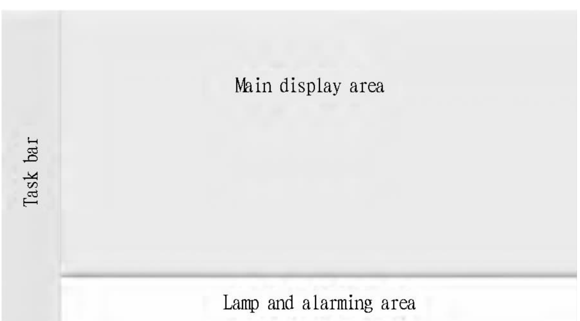


Fig. 1 Overall interface layout

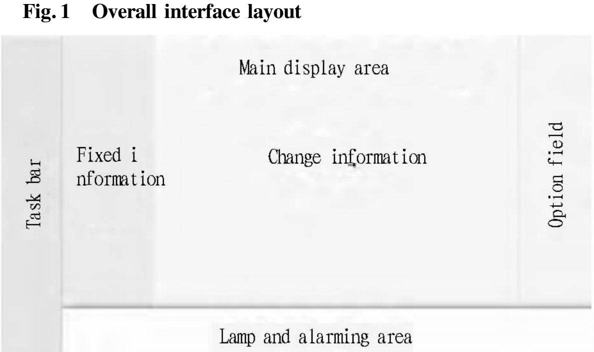


Fig. 2 Specific area division of user interface

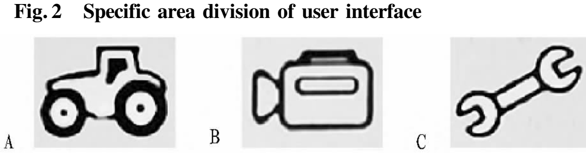
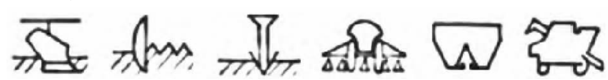


Fig. 3 Icon design: Tractor information (A); Camera monitoring (B), Fault and diagnosis (C)

3.1.2 Lamp and alarming area. In lamp and alarming area, there sets alarming signal lamps, including battery voltage alarming lamp, fuel pressure alarming lamp, cooling water temperature alarming lamp, fuel alarming lamp, inlet pressure alarming lamp, engine self-test lamp, front and back fog lamp, high beam, and left and right steering lamps, as shown in Fig. 4. Icons of alarming lamps are designed with reference to automobile industry standards to facilitate drivers to grasp connotation of lamps.

Fig. 4 Icon design: Lamp and alarming area

3.1.3 Main display area. Main display area displays most important tractor information, including tractor speed, engine speed, residual fuel, cooling water temperature, and oil pressure. After further dividing main display area, when tractor performs different jobs, the right option field can be placed with icons of job types, including plowing, soil preparation, sowing, pesticide spraying (irrigation), fertilizer application, and harvesting, as shown in Fig. 5. After selecting a certain job icon, it enters corresponding job information interface. The fixed information area is placed with common essential information for different jobs, including tractor driving speed, real-time working area, real-time driving distance, and real-time working time. The field of change information displays certain information of different jobs, including plowing depth, harrowing depth, working width, sowing amount, fertilizer amount, pesticide (irrigation) amount, and compressor pump pressure, *etc*.



From left to right: Plowing, harrowing, sowing, pesticide spraying (irrigation), fertilizer application, harvesting

Fig. 5 Icon examples of option field

Observing the interface layout, we can find that task bar and lamp and alarming area enclose the main display area in L form. This method of division is to highlight main display area, reduce the attraction of task bar to driver, and avoid ignoring the lamp and alarming area. Especially after further division of main display area, the fixed information in left side will not be ignored, and it can stress information group in change information field. After entering tractor working information interface of different jobs, lamp and alarming area becomes not so important and thus can be omitted.

3.2 Specific interface design The system interface includes basic information, working information, camera monitoring, and fault diagnosis interface.

3.2.1 Design of basic information interface. The main display area of basic information interface displays important signals of tractor driving and workload information, as shown in Fig. 6. The driving status signal includes tractor speed, engine speed, cooling water temperature, oil pressure, residual fuel, total distance traveled, working area, time, and date; workload information includes real-time driving distance, real-time working area, real-time working time, real-time fuel consumption, total driving distance, total working time, and total fuel consumption, unit time (per house) working area, unit time (per house) fuel consumption, and unit working area (per mu) fuel consumption, *etc*. Except tractor speed, engine speed, total distance, time and date, the rest information is displayed in icons, making the interface more vivid and vigorous. In layout, tractor speed and engine speed are located in center top of the interface and the rest information surrounds in U shape.

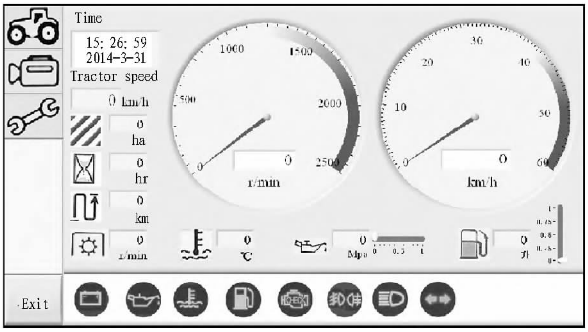


Fig. 6 Basic information interface

3.2.2 Design of working information interface. According to working types and working conditions of tractor, the working information interface consists of plowing, harrowing, sowing, pesticide spraying (irrigation), fertilizer application, and harvesting, and some working interface is shown in Fig. 7. The main display area still indicates information in icons, attached with text explanation, to avoid confusion, and values of specific information are displayed visually in digits. For specific information, like width, input information is set and can be input from interface. Change information field contains much workload information, including unit time (per hour) working area, unit time (per hour) fuel consumption and unit working area (per mu) fuel consumption. Except information displayed in icons, it uses vivid picture to indicate certain job to make the interface clear.

3.2.3 Design of camera monitoring interface. When the tractor is fitted with camera, the camera monitoring interface can help driver to observe objects, make up blind spots of field of vision, and help drivers to grasp working conditions and road conditions, to facilitate eliminating roadblocks and safe driving.

3.2.4 Design of fault alarming interface. When there is fault alarm in the process of tractor driving, select fault and diagnosis icon, it will change to fault diagnosis information interface. This interface not only displays fault cause, but also provides corresponding fault removal methods for driver. In addition, this interface also can provide maintenance information for driver, for convenience of periodical maintenance and extending service life of tractor.

4 Evaluation of user friendly of the interface

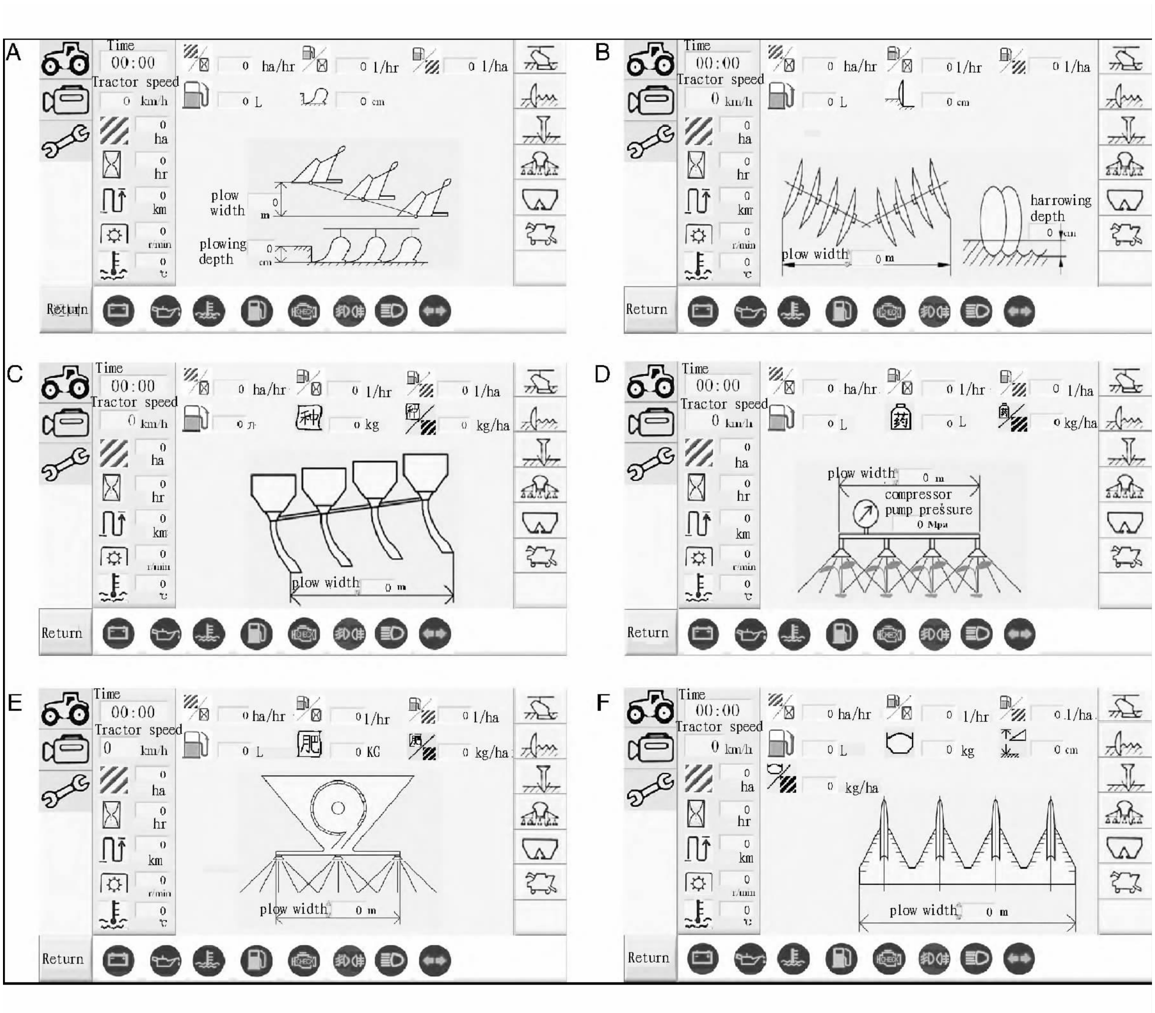
The user interface of information management system changes to physical interface to cognition interface, and pays more attention to availability of the system and interactive relationship between man and machine[16-17]. Apart from accurately reflecting driving status of tractor, the interface should also determine its structure according to physiological characteristics of sense organs. Both aspects should realize full coordination. Shape, color, dial, pointer, and luminance of the interface should adapt to process of user accepting information and cognition, and the information displayed should be rapidly identifiable, highly reliably, and low misunderstanding rate, to alleviate mental nerve and physical fatigue[18-19]. Now, we evaluated the user interface from color, indicator lamp, dial, and pointer.

4.1 Color design Color selection of interface exerts great influence on identifiability of information. To make pointer and dial clear and identifiable, we designed the interface color using clear color matching method provided in ergonomics. Researches show that people can accurately identify 10 – 12 colors at most. Medium wave colors (orange, yellow, and green) in spectrum have highest sharpening action for eyes, not easy to lead to eye fatigue, and identification speed and accuracy are relatively high. According to this result, we used pink red, light blue, light green, and light yellow, having great difference and easy to distinguish different functions of display areas. Besides, to avoid visual fatigue and cognition difficulty, types of colors are few. Furthermore, matching of the above colors is beautiful and coordinated, and easy to make driver concentrate attention.

4.2 Design of indicator lamps Indicator lamps are generally arranged in following three ways, as shown in Fig. 8. Researches show that square arrangement is most difficult to identify, circular arrangement more difficult, and straight line arrangement is easy. Therefore, we adopted straight line arrangement method to arrange lamp and alarming signals. Information provided by indicator lamps should be easy to be perceived by driver. To make the information transmitted by indicator lamps more accurate and identifiable, we designed indicator lamps with reference to automobile industry standard, to facilitate drivers to grasp the connotation. To further attract attention of drivers, all indicator lamps adopt flashing mode. Indicator lamps representing forbidding and danger flash in red, for example, fuel lamp; indicator lamp representing normal operation uses green, for example, steering lamp.

4.3 Dial design Shape of dial mainly includes horizontal straight line, circular shape, semi-circular shape, 1/4 circular shape, and fan shape, as shown in Fig. 9. Researches show that circular shape dial has small range of identification, and centralized field of vision, and low mis-reading rate, but the maximum and minimum scale coincides with each other or the distance is close to each other. Semi-circular dial gives high accuracy rate and display position, but fails to satisfy demand of scale arrangement, even the too crowded scale line may lead to mis-reading. With overall consideration of the above factors, the dial is designed into fan shape slightly larger than semi-circular, which not only satisfies distance requirement between maximum scale and minimum scale, but also increases the spacing between scales.

4.4 Pointer design Pointer shape shall follow the principle of tip head, flat tail and wide middle, and style shall be simple, and



A: Plowing interface; B: Harrowing interface; C: Sowing interface; D: Pesticide spraying (irrigation) interface; E: Fertilizer application interface; F: Harvesting interface

Fig. 7 Working information interface

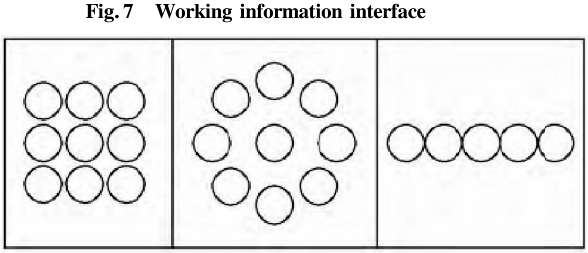


Fig. 8 Arrangement methods of indicator lamps

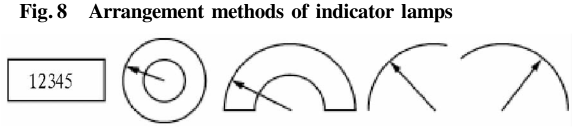


Fig. 9 Dial shape

tip end shall have equal width with the minimum scale line. If it is smaller than minimum scale width, the pointer may be unclear in the scale range; if it is larger than the minimum scale width, the accuracy may be impaired. Besides, pointer color shall form contrast with dial color, coordinate with scale line and character color, to facilitate driver to identify. In all, the user interface we designed can satisfy drivers to transmit their knowledge and experience to this system, to learn and use functions of this function faster, and facilitate drivers to focus on judgment, analysis, search, and sorting tasks.

5 Conclusions

Taking tractor driver as center and fully considering operating habits of drivers and hostile environment, we designed user interface for real-time information management system for tractor cab, to assist drivers to perform corresponding tasks in high quality efficiently.

(i) Interface layout conforms to cognition psychology and operation habits of drivers, has certain hierarchical and logic advantages, and is easy to get familiar and grasp.

(ii) The basic information interface displays the most important tractor information, helpful for drivers to grasp driving status in real time.

(To page 61)

management system for operators and system administrators. Every operator should do every step of work in strict accordance with requirements, to avoid problem of certain link leading to failure of subsequent work and consequently influencing work progress. Besides, it is recommended to ask system administrators to make regular maintenance and data backup, to avoid computer virus damaging system and leading to data loss or corruption.

4.3 Carrying out integrated management of temporary database, current database and historical database in case of change of database At present, changes in majority land survey database are stored in current database and historical database. Such operation is handled by input operator after inspection of data quality of changed data package. Current database is changed directly for cadastral data and the data before change would be input into historical database. Such mode empowers all powers of database entry to the operator. The power is excessively centralized and free from supervision. Once there is any error or inconsistency in data change, it will be difficult to locate and will inevitably bring hidden trouble for future work. Therefore, it is recommended to carry out integrated management of current database, temporary database, and historical database. Database entry operator should store changed data in temporary database for the time being and does not make change of current database until the person handling checks, examines, and approves. In the event of any problem found, it can return promptly and the database entry operator can correct the error. This improves management mode of land survey database.

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(iii) According to difference of working conditions, the working information interface consists of plowing, harrowing, sowing, pesticide spraying (irrigation), fertilizer application, and harvesting, helping drivers to grasp working conditions of tractor and increase working efficiency.

(iv) The camera monitoring interfaces monitors ground working conditions beyond field of vision of drivers, helping drivers to grasp more working information.

(v) The fault diagnosis interface provides signal alarming, fault alarming, fault diagnosis and maintenance information, removes faults and provides maintenance advice for drivers once there is fault, and assists drivers to make routine maintenance and extend service life of tractor during normal drive of tractor.

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