

Design of Portable Power Maintenance Products Based on Human-Computer Interaction

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Abstract: The construction of the new power system has made power operation and maintenance increasingly complex. The traditional operation methods can no longer meet the requirements of high efficiency and high safety. Based on the operation scenarios of the frontline power operation, this paper studies and designs a portable operation terminal based on human-computer interaction logic. After in-depth analysis of the operation behaviors and cognitive psychology of the operation personnel, a system framework consisting of hardware human engineering, graphic interface visual communication, and multimodal interaction feedback is obtained. During the product design process, the grip stability of the terminal in extreme environments, the comfort of wearing, and the touch and voice interaction strategies under complex electromagnetic interference were mainly studied. Through the research, it is known that the improved interaction design can effectively reduce the cognitive burden of the operation personnel, reduce the risk of misoperation, and enhance the accuracy of power fault diagnosis and data collection. The research in this paper provides rigorous theoretical basis and design practice references for the intelligent and humanized transformation of special portable equipment in the power industry.

Keywords: Human-computer interaction; Power operation and maintenance; Portable product; Industrial Design.

1. Introduction

Power operation and maintenance is an important part of energy supply security, involving many tasks such as inspection, fault repair, and equipment debugging. The operation personnel usually work in substations, enclosed cable trenches, or high-altitude towers, and they need to wear insulating gloves and safety helmets as protective equipment. Traditional operation tools or general intelligent terminals (such as ordinary mobile phones, tablets, etc.) have problems such as complex interface interaction logic, difficulty in single-hand operation, poor readability of the screen in strong or weak light environments, and unstable communication under high voltage and strong electromagnetic interference. The core of human-computer interaction (HCI) design is to form an efficient interactive information flow between people, machines, and the environment [1].

2. In-depth Analysis of Power Maintenance Work Scenarios and User Requirements

2.1. Special Constraints of the Complex and Harsh Physical Environment on Hardware Interaction

The space range of power maintenance is very broad, it goes from those dark and stuffy cable wells under the ground to the transmission towers in high mountains at low temperatures, from the small and crowded high-voltage cabinet inside the substation to the outdoors where everything is exposed to direct sunlight. This is sorta a pretty tough physical environment like this for any portable kind of thing. The first thing is that we lose tactile, finer movements because of protective gear. Insulation test, live measurement, etc., the worker needs to put on thick insulating gloves or even insulating sleeve. The traditional touch screen relying on humans' bio-capacitance can completely stop working or

produce very bad coordinates when a thick insulating glove is put over it, so normal operations like point pressing and sliding cannot be done anymore, factory workers have to take off their gloves often to press buttons, this makes things much harder and dangerous. Second, it's extreme optical condition cuts out vision [2].

2.2. High Cognitive Load and Multi-Task Concurrency Psychology Needs

Power maintenance people also have to deal with an incredibly harsh internal psychological environment and a huge amount of cognition in the operation. Power outages repairs and defects are frequently under pressure situations, with many things happening at once. People have to keep an eye on how high voltage stuff is running, hear the faintest discharge sounds and take a look at very complicated electricity wiring pictures via handheld devices continually in fear of getting zapped or falling down. In this high stress and also very scattered mental state, peoples short-term memory amount of information that can be processed at once will drop drastically [3].

3. Interaction about traditional portable things for power failure maintenance

3.1. Forms do not go with ergonomics

In the current market, the hardware form of a large amount of industrial three-proof tablet or PDA handheld terminal distribution for grassroots power team is often full of ergonomics disconnection problem. The IP level of protection is purely for fear of drops, water and dust, these things come with such heavy rubber and metal that a single device weighs well over a kilogram. It's even more tragic that their internal batteries, motherboards have also only considered the difficulty of engineering implementations; they did not take into account the overall center of gravity distribution of the product itself. And if maint. Per's grasp this heavy - light

thing w/ 1 hand in the air as they walk it long-distance recording data at great heights there is going to be some big pain in the wrist area! Additionally, there's no button or unreasonable position of the button as well is also a drawback. A lot of devices for sake of having more screens removed navigation key and shortcut key or make the button too small to feel like it is pressing.

3.2. Cacberry: Confusing Interface's Information Hierarchy, Lagging Backward Feedback

Regarding the Software Interactions, most of today's available power Outage maintenance systems use traditional b/s architecture background management System interface with force to narrow the form of an smartphone, a bad and terrible Experience. The first one is the information is very confused. The interface is stacked up with a great deal of small data tables and cluttered text that has no relation to what we're doing, the actual core operation buttons like 'Start Recording', 'Defect Reporting' and 'Emergency Stop' are hidden way down inside all the fold-out menus. The 'Full Data Display' without the scene based filter will force O&M personnel to find the needle in the haystack among all this visual noise which significantly increases their visual search time. Secondly, The sizes of the Interactive Controls do not Follow Fitt's Law in Any Way. The touch hot zone is too little and the safety zone around the control is not sufficient. When worker wears glove or have oily fingers then fat fingers occur quite often and touching adjacent options, which result in lot of corrections.

4. Innovative Design Strategies for Portable Products Based on Human-Computer Interaction

4.1. Physical form and Ergonomics reconstruction according to HCI concepts

To solve the problems related to hardware interaction, portable products that are based on the concept of human-computer interaction should completely redesign their physical forms. Key idea is adapt for people size and improve hands on feel. In terms of the first point concerning the shell shape, we need to fit the surface curvature with a 3D hand shape database and create asymmetric non-symmetric anti-slip grasping sections on the back or side of the device so that it matches the natural bend of the palm's curve. The internal components like big batteries should be placed as far down as possible, so that the center of gravity for the thing is close to where your hand meets the palm (palm crease), which lets you use some of the bones under your palm to hold up most of its weight and makes it much easier to keep your wrists relaxed. The second point is we need to bring back the absolute physical button. Near some close-to-screen things or parts like skirt it has much more independent mech key buttons (long travel) and set it even little more damp, but it's much easier/frequent to operate: scan barcode, take proof pic, one click call. And then those buttons, they require massive key travels to give you this sort of micromotion dampening for a good crisp click - so much so, we could even do full zero visual operation on thick insulating rubber gloves! Besides, it's necessary for the material of the device shell having great resistance against dropping besides high strength so as to add a skin friendly anti slip coating which is with super friction

under various conditions like contaminated by insulating oil or rain. And at the same time, if one has to prevent from falling when doing high-altitude works, the person can be integrated with strong hanging rope holes or quick release buckle fastener on their back so the devices could hang safely by chest/ or waists of the worker, freeing all workers hand and removing the human engineering obstruction from the physical level.

4.2. Scenario based adaptation of Graphical User Interfaces(GUI)

As for how to cure it, just convert all this stacking thing centered on the function into the task-oriented -scenario adaptive-GUI solution. The design team needs to thoroughly examine the standards operation procedure SOP of power check, defect removal and switching operation, and take out the most essential information set for various workflow at certain time point. At the level of interfaces, "cards" and "flat", these should be carried through. When the system determines by GPS location that the operation and maintenance staff have reached a certain substation, the home page menu should hide irrelevant items and push the task cards with to-dos for the current site, as well as the latest infrared temperature-measurement history image taken recently and a brief piece of equipment ledger information. Regarding visual element handling, it is based on the principle of using very bright backlight and combining black and white high-contrast vector line in outdoor strong light mode, as well as dark background with de saturated information in night dark mode so that pupils dont contract too much when its nighttime. And the control size has to be enlarged to its maximum. All key operation buttons physical touch-sensitive area like "Confirm", "Reject" etc. cant be less then 15*15MM, also the destructive operation such as "Delete Data" should be physically isolated from other normal operations with blank white space which has obvious difference. When it comes to more complicated multi level actions, the system must have an "advisory" interface, breaking down long form into one page process that has clearly marked progress bar to indicate where we are at. This can drastically reduce short term memory load on user and make human machine interface work like traffic sign – simple, straight forward and fail proof.

4.3. Set up a multi-level feedback check with listen + sense

Power operations are usually very complicated, so if there is a visual block from powerful light or the focus on something dangerous like equipment, a single screen's worth of visual feedback would be very fragile and untrustworthy. Think of these multi - Channel Human-Computer Interaction theories, Portable devises need to construct a multi-layer reinforcement feedback sytem consisting of audio and tactile. For the tactile channel part, we need to use LRAs(Linear Resonant Actuator) or ERM(Eccentric Rotating Mass) motors as internal equipment. It is different from smartphone that adopts Micro Rotor Motor. It needs Industrial Vibration Level. System could arrange different tactile vibration mode by the urgency of this task as well as attribute of result. So, imagine something like how if an RFID gives out a small successfull but not that great of a notyfication of it reading, and if it sees that the difrences is big compared to usual historic thresholds values (which could be due either from bad input or really huge machine fault) than do long rapid three vibration warning as very physical warning. In Auditory Channel,

Considering there is very strong Low-Frequency Electromagnetic Noise and Strong Mechanical Roaring Sound in the Generator Room or Transformer. We Must Avoid The Concentrated Frequency Of This Environment's Noises And Use Extremely Penetrative Mid-High-Frequency Buzzes Or Some Specified Synthesis Of Frequencies And it can also make seamless direct contact with the noise-canceling safety helmet communication headphones that the operators are wearing, based on the Bluetooth standard, and transmit the main system operation feedback, background command center's voice orders, equipment malfunction alarms etc. to the ears of the maintenance workers in the way of bone conduction or ear-to-ear voice broadcasting. This visual touch sound 3d interactiv feadback linr makes suure we got info intractio lnk frm us t mch ney sc.

5. Intelligent empowerment: Intelligent empowerment is the application of ai and ar intelligence for interactive design.

5.1. Augmented Reality (AR) Technology in Visual Interaction for Concealed Engineering Inspection

With the improvement of spatial computing Technology , AR technology opened a brand new disruptive Frontier Dimension For Visual Interaction In Portable Power Operation Device. For traditional operations inspection work requires the operator do multiple conversions and imagine of space relations between 2D electrical diagrams with actual physical cabinets which is very time consuming and easily cause wrong judgement. We used AR to put into our mobile devices, which has a large camera on its back and some other things like a depth sensor, this is how those two worlds interacted. Operators just need to hold the portable terminal, and then point at the complex high-voltage switch cabinet or the complicated secondary wiring terminal block in the substation. It can also very exactly show up all sorts of those hidden wiring roads, 3D topological structure information like the past fault points data etc. as semi-transparent and strong contrast layers overlaying over the specific entity's picture in front of you. And also, this see it as u get augmentation visual interact model takes away that mental block off transform froM diagram. And when we do things like complicated lines connection, fault isolation operation and so forth, AR interfaces could also generate 3D dynamic guiding arrow just like game, guiding operator to put probe at right physical terminal one step by one. It greatly speeds up the process of locating defects and makes it much harder for people to deliberately make mistakes like accidentally wandering into other intervals or reading terminal numbers incorrectly through some trick to avoid, pushing the visual interactive efficiency of industrial portable devices all the way up.

5.2. Nalural Language Processing (NLP)-base intelligent Voice -Assisted System

Like climbing on a tall power tower, both hands tightly gripping the safety line like walking in the small passages, flashlight is held one hand, insulated tools are carried by another hand. Screens can't be touched anymore as they will

die or become impractical. It is at this moment that a AI voice assisted system depending on NLP becomes the best way to communicate. Taking into account the particularity of the power industry, we need to have a small size offline NLP language model which is strongly pre-trained by power profession words and solve the problem of cloud-based voice assistant cannot use in the area without any signal. The operator says a wake-up phrase and gives orders like "Record the error. There is an awful flash on the B phase insulator and must arrange a power outage change as soon as possible." not only can this system precisely change extensive phrases of voice into certain forms, but it also can have a kind of sense meaning to make by itself to automatically select main label entity figures such as 'B-phase', 'insulator', 'flashover' and put these ones in order with their respective columns marked by different defect levels. Then after we've done the recording it'll repeat and confirm with speech synthesis (TTS) And the non contact "voice contro" voice control interaction design completely frees both hands,eyes and let them focus only on themselves and diagnose which parts to check. AI+NLP makes now go from being a cold passive machine, to a smart digital learner who catches what's on your professional voice and does the judging work for you - this opens the door so that people can start talking to machines:

6. Conclusion

The creation of portable power operation equipment is no easy task to translate that simple shell reinforcement technology over to the consumer electronics sector. It is a comprehensive project, it involves deep combination of ergonomic, cognitvie psychology, harsh enviroment physics and latest infomation technology. In this paper we do a quick level review concerning hci as far as the trouble and difficulty when there is an intense physical constraint coupled with much mental strain to the power operating and maintenance. And then offers a whole different type of creative-strategy framework – from reinventing our shapes-hardware, to tweaking & improving the software GUI dynamically, all the way down to building out many kinds of Modal and Dimensional Feedback Systems: It is also shown in studies if human interact with machines by using an interactive interface it will make lives easier for frontline operator/maintenance worker that are under constant pressure. It would probably also reduce error due to unclear system and no feedback.

References

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