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White Paper

Year 2017

Guidelines for designing touch-screen user interfaces

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1. Indications on methodology. Good design outlines.

When attempting to identify a few key indications that may guide the design engineers in defining the characteristics of a new product or, in this specific case, of a new user interface used to control an industrial production machinery, we always need to refer to a few well-defined and clear principles, which aim to enhance the usability level of the interface to be designed.
In principle, the usability of a device for carrying out a particular activity or a specific task is connected to its level of:

• **efficacy**, in other words the degree of orientation to the task and to the activity;
• **efficiency**, in other words, ease of learning, of remembering, of reduced number of errors that take place during its use and its use under conditions of safety;
• **satisfaction**, in other words the compatibility with the needs of the users and the level of pleasantness that derives following its use.

Based on these criteria, which will have an impact on the usability of the device, and which will also be considered during the design phase, certain principles known as "good design" (Norman, 1988) have been identified. These principles provide the high-level ergonomic guidelines that the designers must comply with in order to develop an interface that is usable and meets the expectations of the interested users.
Below please find the principles of good design:

• **provide visibility** (make the functions visible);
• **provide a good mapping** (create clear space-logic relationships between the controls and the effects of their use);
• **provide affordance and restraints for use;**
• **provide feedback** (provide feedback information following each action) ;
• **provide a good conceptual model.**

Visibility is a "mnemonic reference" of what one can do with a product, in other words, the need to indicate in a clear and non-questionable manner where one can find what he needs for the proper execution of an action or use of the product. Visibility allows the control itself to specify how the action must be carried out; moreover, all functional parts must be visible and convey the proper message on what can be done.
A good indication is to arrange so that the number of available functions does not greatly exceed the number of controls that can be used.

Good **mapping** requires an explicit relationship between the controls, their operation and the results deriving on the external world; when the **mapping** is natural (Norman, 1988), physical analogies and cultural models are exploited to obtain the effect of immediate an unambiguous understanding.

Affordance is the real and perceived properties of an object. They encourage a certain method of use of the object, making such method clearly perceivable.

The **constraints** are functions that force the user to use the instrument in a certain way. Hence, affordance and constraints are used to guide the interaction between the object and its user.

Feedback is the principle based on which a piece of information tells the user which action has been carried out and which result has been achieved.
Lack of clear **feedback** may lead the user to make a mistake.

A good conceptual model of the system underlying the interaction between an object and the final user requires for the conceptual image of the system itself to provide basic information in order to understand the structure and its operation. Hence, the overall picture must be self-explanatory to the user: the theoretical model presumed by the design engineer must be as close as possible to the mental model which is created by the user during the interaction with the system.

Moreover, certain concepts are at the base of the object ergonomic design process called UCD, **User-Centred Design**, which requires the final user's active participation in the practices and in the activities, that will lead to the realisation of a new product or to the planning of a system.

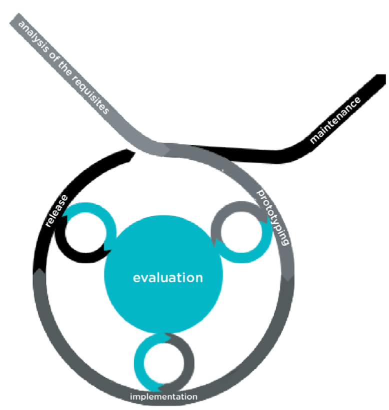
The basic principles of User-Centred Design can be summed up as follows:

• placing the user at the centre of the deign process - **user-centric methodology**;
• verify in itinere that the project meets the needs of the user - **test-design iteration**;
• modify the realised system based on experimental feedback obtained from tests carried out with the users - **re-design**.

User-Centred design required in-depth knowledge of the common and peculiar characteristics of the individual that will be the final user of the object being designed.
Once defined this, a potentially representative sample of the users needs to come into play in the design for the entire development process.

In terms of the user, we need to know both the characteristics of their cognitive system, and the characteristics of the activity which they carry out and, consequently, the user's attitudes and expectations vis-à-vis the activity and the product or the system itself.
In order to do so, and so that the user becomes an active part of the design process, you need to include them in such process since the very first stages of the design and to constantly measure the results of their interaction with the design engineers and with the prototypes that will be developed and tested.
The man-object system must be tested as a whole several times, verifying/checking each time the results of the choices made and of the changes carried out based on more or less pre-established criteria.

The design must have a truly cyclic nature (design, test, re-define, re-design).



Picture 1: Conceptual diagram and User-Centred design cycles

User-Centred Design requires for some of the process phases to be repeated multiple times, following a cyclic or iterative trend. Thanks to this cyclic structure, we can verify the validity of the design engineers' assumptions with regards to the characteristics of the activity to be supported and the type of technical solution to be adopted in order to meet the users' needs, objectives and expectations.

UCD offers various advantages, for both the users and for the organisation, which applies it as a design model for its products, systems or services. As regards the final users, they will certainly feel the impact due to having been represented during the design phases and the direct influx that the expressed requites, the real needs and the context of use of the object entail in the final use enjoyed by the users.

The following derives from the above:

- easy use and learning;
- complete efficacy and efficiency of the man-machine system;
- pleasant use;
- safeguarding of existing skills and, potentially, of new ones;
- reduced training costs.

About the organisation directly involved in the design, there will be higher initial costs to be incurred, however the total costs will certainly be lower. Through User-Centred Design, there is a reduction in the validation work of the requisites during the advance development phase of an object and during the development process. Unnecessary training and assistance is eliminated after product release.

The benefits deriving from application of the User-Centred design methodology can be summed up as follows:

- compliance with the user's real requisites;
- identification of new needs and market opportunities;
- reduced acceptance time on the market;
- reduced development, maintenance and training costs.

2. Guidelines for redesigning

Below please find a list of some indications of a general nature for developing the composing elements and for creating the interface layout.

1. The entire interface shall be consistent, in other words all the used graphic elements shall, if graphically identical, convey the same surfing method or action.

2. There must be uniformity in terms of graphics and style, with an approach as minimalist as possible for avoiding possible distractions, focusing the operator's attention on possible actions or on the displayed information, and attempting to prevent any type of error, thus improving the efficiency of the machine.

3. The interface space shall be organised in a rational manner, allocating specific functional areas to defined tasks. The functional areas, if always visible, shall be proportional to the relative importance they cover in the interface, to focus the user's attention and to avoid conveying information which is not pertinent.

4. If possible, the keys used to browse through the pages must be distinguished in terms of shape and colour (i.e., switching between different sections of the interface or to other menus), as well as the keys used to surf inside the page (e.g., scroll or page turning) as well as the function keys that convey an action. This makes it possible to predict the consequences of the operations carried out on the user interface, hence limiting the errors made.

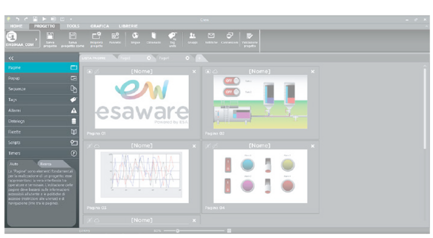
Picture 2 Example of differentiation between the surfing buttons and the function ones.

5. One can arrange for making the interface structure and its functional architecture always visible, minimising, by doing so, the number of operations needed for switching from one section to another. This can be obtained by granting direct access to the various system sections though surfing buttons of the first-level menu always visible and arranged vertically on one of the two sides of the screen or at the bottom. The solution with the menu at the bottom offers the advantage of not being limiting for left-handed (or right-handed) individual, since the hand does not cover up parts of the screen.

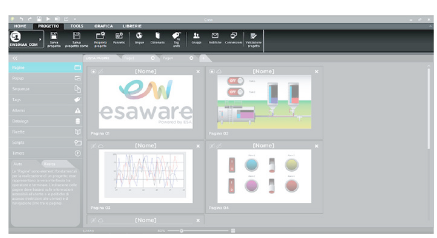
6. In case ever-present menu items are used, it is recommended to use the **toggle**[1] controls, where the made selection is always visible (active interface area) as well as the current operating mode.

7. To help the users find their way while navigating through the interface and its section, you can assign titles to the pages with the help of **breadcrumbs**. **Breadcrumbs** are a navigating tool that shows the hierarchy of the pages from the homepages up to the location where the user is, with graphics and text elements.

8. Each control located on the interface must be spaced out based on ergonomic guidelines to allow its proper identification, pointing and pressing. This makes it possible to better focus on the interface elements and consequently minimise the chances for pressing errors.



Vertical menu

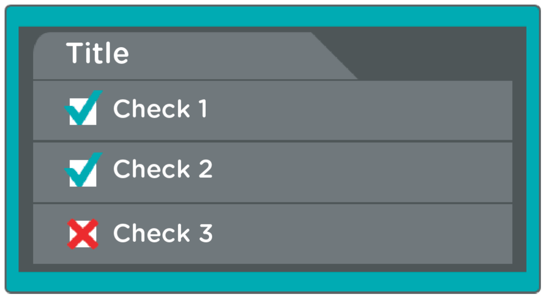


Horizontal menu

Picture 3 Example of visible menu (toggle controls, breadcrumbs)

[1] Toggle controls are controls that have two states, typically indicating that the function is active or not active, or on and off. Reversing the state is usually done by a single pressure, regardless of the state the control is currently in (e.g, the switch to defrost the rear window on automobiles is a toggle control).

9.The operator always needs to be kept informed with regards to the operations being carried out by the machine and the state it is in. This applies both when there is an automatic or semi-automatic procedure in progress, or during production or when an alarm is triggered. In case of automatic procedures, if possible, the various passages must always be indicated, along with their satisfaction and progress status of any procedures requiring a longer period of time.



Picture 4 Example of checklist and progress status in semi-automatic procedure

10. There is a need to identify soon whether or not to use controls bearing a text label, an icon label, or a mix of the two. All solutions feature strengths and weaknesses that will have to be considered also in light of the reference markets[2].
In case it is possible to identify icons that convey a clear and univocal meaning, these icons could be used completely for the main controls and for the menus.

11. It is necessary to maintain consistency and uniformity in terms of the measures and the values, including technical ones, displayed in the various interface screens. Uniformity should also be present when talking about the methods for changing or setting these values.

12. The machine status could be kept always visible in a special section of the interface (e.g., status area or bar) so as to provide the user clear information, always visible, immediate and identifiable as regards the machine status and any supplementary information (e.g., presence of warnings, time, etc.).

Vertical status bar **Horizontal status bar**

Picture 5 Example of status bar positioning

[2] Different languages may have a strong impact on the organisation of the spaces and text fields of the interface. Words with the same meaning may, for example, significantly vary in terms of length of the text depending on the language, as well as in the set of characters. Other problems, for example tied to the interpretation of symbols, are instead present in case of ideogram languages such as Chinese.

3. Graphic User Interface design indications

3.1. Premise

Identify an accurate and precise HMI interaction philosophy. This should define, in the form that is as accurate and anticipatory as possible, the aspects listed here below:

• Which are the sensitive areas and which are not;
• What are the normative constraints, the user's needs and desires, but also the needs of the producers, of the system operators or of the design engineers;
• What happens after I press my finger on the screen in the various conditions (of the finger, of the machine and of the display);
• When the "event" is transmitted to the system (e.g., upon release);
• What is the overall conceptual model of the system and how it is defined and presented through the user interface;
• Which are the functional areas of the interface and how are they set up;
• Which are the action controls and the navigation controls of the user interface and how they are made. Definable in the different statuses. Define the display fields and the editing ones;
• Define a subset of components or composing graphic elements;
• Define the colour codes, if functional or dictated by regulations or other laws.

3.2. High-level guidelines

The guidelines listed herein are useful for optimising the functional capacities and usability of the HMI system.

• **Conceptual model:** supply a general system regarding how users may think about the user interface. For example, the mental projection that the users have on how the software works and on the interaction with the machine.

• **User-interface structure:** design the screens according to a logical hierarchy that takes into consideration how people prefer to differently approach frequent, urgent and critical operations.

• **Interaction style:** establishing an interaction model between the user and the software application that makes the tasks easier and embraces the user's abilities while understanding their needs.

• **Screen subdivision:** organise information on the screen so that users can quickly identify specific elements and make appropriate associations, minimising attribution errors.

• **Legibility:** the displayed textual and graphic information must be clear in terms of dimension, colour, contrast, type of character, so that users may read and discriminate important details.

• **Aesthetics:** the information must be presented in an attractive manner so as to avoid intimidating new users and positively affect the performance of the applications.

• **Data entry:** establish precise rules on how to enter data or carry out selections through the interface.

• **Colour:** use colours to significantly contribute to making the information clear and focus attention on the more important pieces of information. Pay attention to codes and redundancies.

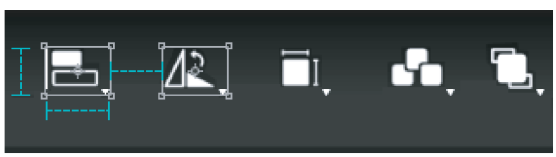
• **Dynamic display:** use active or dynamic graphic and text elements (e.g., short animations) to convey information in a manner that is more convincing than it would be if static presentations were used.

• **Special interactive mechanisms:** provide clear information with regards to less common control mechanisms, such as soft keys or keyboards on screen. These touch-screen controls are not always obvious and identifiable.

• **Support to the users:** provide the users with useful information and help at the right time and in the proper format so as to help them carry out their tasks safely, quickly and effectively.

• **Consistency:** try to provide the same type of checks and feedback, when possible. Both in terms of interaction and in terms of Look&Feel.

3.3. Physical characteristics: sizing of commands on GUI (source: US DoD, MIL-1472G, 2012)



Picture 6 Sizing of commands on GUI

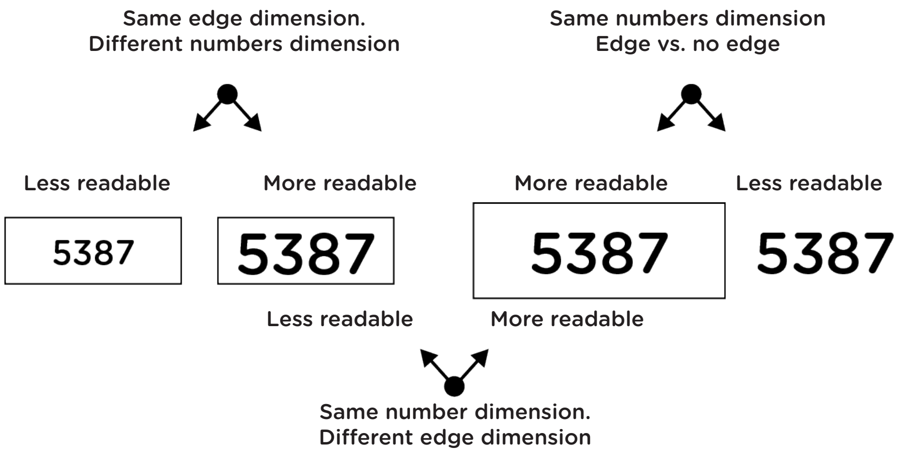
	ALPHANUMERICAL / NUMERICAL KEYBOARDS		
	Entering area (A)	Separation (S)	Resistance
Minimum	-	0	250 mN
Optimal	13 x13 mm	-	-
Maximum	-	6 mm	1.5 N

	OTHER APPLICATIONS		
	Editing Area (A)	Separation (S)	Resistance
Minimum	16 x 16 mm	3 mm	250 mN
Maximum	38 x 38 mm	6 mm	1.5 N

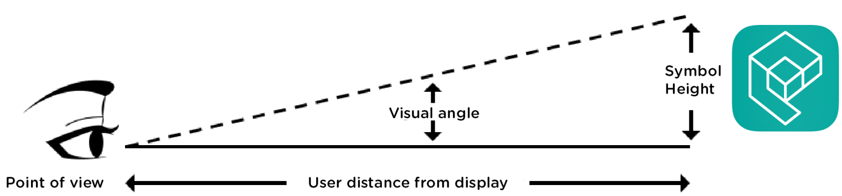
The keys of the graphic interface of a **touch-screen** display should have a regular shape, symmetrical and tendentially equilateral.

3.4. Dimension of alphanumerical characters and symbols (source: US DoD, MIL-1472G, 2012)

View distance (mm)	Minimum character height (mm)
<500	2.3
500 - 1000	4.7
1000 - 2000	9.4
2000 - 4000	19
4000 - 8000	38



The symbols must comply with the prescriptions contained in EEC Directive 78/316 and in standard ISO 2575, when present.



$$\alpha_A = 3438 \times AS / DU$$

Picture 7 Distance from the display and visual angle

• The minimum contrast requested between the symbol and the background is 3:1;
• To guarantee legibility, the minimum visual angle of the symbol is 41 arcmin (0.69 degrees) which, at a distance of 850 mm, are equal to approximately 10 mm;
• The optimal visual angle of the symbol is 85 arcmin (1.43 degrees) to ensure recognisability;
• The minimum visual angle for a text label is 16 archimin (0.27 degrees);
• The optimal visual angle for a text label is 24 archimin (0.40 degrees).

3.5. Colour code, polarity and combinations

Touch-screen devices and the relative GUI give great importance to the stylistic Look&Feel and to the colours used for the various sections and type of areas and controls of the interface. If a "color code" is used, this should be made redundant by means of another type of identification code (e.g., positioning, dimension, etc.) The single colour code should never be used as an identifying element.

Polarity and luminance of text or symbols on the foreground and backgrounds:

• **Positive:** dark symbol against a light-coloured background. For non-shielded displays: the positive polarity helps to reduce the visibility of reflections.
• **Negative**:light-coloured symbol against a dark background. At night: use negative polarity.
• The minimum luminance ratio between characters and background must be as follows:
– 5:1 at nights;
– 3:1 during the day (cloudy);
– 2:1 during the day (sunny).

Colour combinations:

• When symbol and background are of a different colour, the minimum luminance contrast must be guaranteed.

	Symbols colour						
Background colour	White	Yellow	Orange	Red, Crimson	Green, Cyan	Blue, Purple	Black
White		-	O	+	+	++	++
Yellow	-		-	o	o	+	++
Orange	o	-		-	-	o	+
Red, Crimson	+	O	-		-	-	+
Green, Cyan	+	O	-	-		-	+
Blue, Purple	++	+	o	-	-		-
Black	++	++	+	+	+	-	

Combinations of colours	
Excellent (preferred)	++
Good (recommended)	+
Sufficient (Acceptable with huge differences of saturations)	o
Insufficient (not recommended)	-

4. Reference standard for the design of User Interfaces on Touch-screen devices

Standard	Title	Main indications
ISO9241-110 (2006)	Ergonomics of human-system interaction - Part 110: Dialogue principles	It defines the cornerstones of Human-Machine Interface and the sets the bases for the assessment heuristics of user interfaces within the scope of human factors.
ISO11064-4	Ergonomic design of control centres	Legibility - It defines the legibility aspects in designing workstations, with special emphasis on layout and sizing.
MIL-STD1472G (2012)	Department of Defense design criteria standard: Human engineering	The aim of these regulations is to present criteria and human factors in a context of engineering design, principles and practices to optimise system performance, taking into full consideration the human abilities and limitations as a part of the overall project.
ANSI/HFES 100 (2007)	ANSI/HFES 100-2007 Human Factors Engineering of Computer Workstations	Criteria, guidelines and specifications for the design of workstations. General guidelines for posture and accessibility.
ANSI/AAMI HE75:2009	Human Factors engineering - Design for medical devices	Criteria, guidelines, regulations for HMI design from the standpoint of ergonomics.
ANSI/AAMI HE75:2009	Zwahlen, H. T., Adams, C. C., DeBald, D. P., DeBald, Jr,, "Safety aspects of CRT touch panel controls in automobiles", in Gale, A.G. et al., Vision in Vehicles II. Elsevier, 1988	Impact on the safety of touch-screen devices. The Automotive domain has been deeply studied. Observations, suggestions and guidelines for design may be evaluated and considered valid in other domains as well.

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