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Ergonomics of human-system interaction —

Part 910:
Framework for tactile and haptic interaction

Ergonomie de l'interaction homme-système —

Partie 910: Cadre pour les interactions tactiles et haptiques

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Foreword

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ISO 9241-910 was prepared by Technical Committee ISO/TC 159, *Ergonomics*, Subcommittee SC 4, *Ergonomics of human-system interaction*.

ISO 9241 consists of the following parts, under the general title *Ergonomic requirements for office work with visual display terminals (VDTs)*:

- *Part 1: General introduction*
- *Part 2: Guidance on task requirements*
- *Part 4: Keyboard requirements*
- *Part 5: Workstation layout and postural requirements*
- *Part 6: Guidance on the work environment*
- *Part 9: Requirements for non-keyboard input devices*
- *Part 11: Guidance on usability*
- *Part 12: Presentation of information*
- *Part 13: User guidance*
- *Part 14: Menu dialogues*
- *Part 15: Command dialogues*
- *Part 16: Direct manipulation dialogues*
- *Part 17: Form filling dialogues*

ISO 9241 also consists of the following parts, under the general title *Ergonomics of human-system interaction:*

- *Part 20: Accessibility guidelines for information/communication technology (ICT) equipment and services*
- *Part 100: Introduction to standards related to software ergonomics* [Technical Report]
- *Part 110: Dialogue principles*

- *Part 129: Guidance on software individualization*
- *Part 143: Forms*
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- *Part 171: Guidance on software accessibility*
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- *Part 300: Introduction to electronic visual display requirements*
- *Part 302: Terminology for electronic visual displays*
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- *Part 304: User performance test methods for electronic visual displays*
- *Part 305: Optical laboratory test methods for electronic visual displays*
- *Part 306: Field assessment methods for electronic visual displays*
- *Part 307: Analysis and compliance test methods for electronic visual displays*
- *Part 308: Surface-conduction electron-emitter displays (SED)* [Technical Report]
- *Part 309: Organic light-emitting diode (OLED) displays* [Technical Report]
- *Part 310: Visibility, aesthetics and ergonomics of pixel defects* [Technical Report]
- *Part 400: Principles and requirements for physical input devices*
- *Part 410: Design criteria for physical input devices*
- *Part 411: Evaluation methods for the design of physical input devices* [Technical Specifiction]
- *Part 420: Selection of physical input devices*
- *Part 910: Framework for tactile and haptic interaction*
- *Part 920: Guidance on tactile and haptic interactions*

The following parts are under preparation:

- *Part 154: Interactive voice response (IVR) applications*

Human-centred design and evaluation methods, optical characteristics of autostereoscopic displays, and requirements, analysis and compliance test methods for the reduction of photosensitive seizures are to form the subjects of future parts 230, 331 and 391.

Introduction

Tactile and haptic interactions are becoming increasingly important as candidate interaction modalities in computer systems such as special-purpose computing environments (e.g. simulation) and assistive technologies.

While considerable research exists, it involves a wide diversity of terms, meanings of terms, viewpoints, software and hardware objects, attributes and interactions. This diversity can lead to serious ergonomic difficulties for both developers and users of tactile/haptic interactions.

This part of ISO 9241 provides a common set of terms, definitions and descriptions for the various concepts central to the design and use of tactile/haptic interactions. It includes basic guidance (including references to related standards) in the design of tactile/haptic interactions. It also provides an overview of the range of tactile/haptic applications, objects, attributes and interactions.

Ergonomics of human-system interaction —

Part 910:
Framework for tactile and haptic interaction

1 Scope

This part of ISO 9241 provides a framework for understanding and communicating various aspects of tactile/haptic interaction. It defines terms, describes structures and models, and gives explanations related to the other parts of the ISO 9241 “900” subseries. It also provides guidance on how various forms of interaction can be applied to a variety of user tasks.

It is applicable to all types of interactive systems making use of tactile/haptic devices and interactions.

It does not address purely kinaesthetic interactions, such as gestures, although it might be useful for understanding such interactions.

2 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

2.1
haptics, noun
sensory and/or motor activity based in the skin, muscles, joints and tendons

NOTE Haptics consists of two parts: touch and kinaesthesis.

2.2
haptic, adj
appertaining to haptics

NOTE While there is no difference between *haptic* and *tactile* in most dictionary definitions, in the area of haptics, researchers and developers use *haptic* to include all haptic sensations, while *tactile* is limited to mechanical stimulation of the skin. In ISO 9241, the word *haptic* covers all touch sensations and *tactile* is used in a more specific manner. Also, both terms can be used together to assist in searches.

2.3
touch
sense based on receptors in the skin

NOTE Cutaneous receptors are used for the perception of touch.

2.4
cutaneous
belonging to the skin

NOTE Cutaneous receptors respond to mechanical stimulation and temperature changes.

2.5
tactile
appertaining to touch

2.6
vibrotactile
vibration-based stimulation of the skin

EXAMPLE A cellular phone uses vibrotactile stimulation to alert the user.

2.7
kinaesthesis, noun
sense and motor activity based in the muscles, joints and tendons

NOTE 1 Kinaesthesis includes both input and output.

NOTE 2 Receptors in the muscles, joints and tendons are used for the perception of kinaesthesis.

NOTE 3 Muscles, tendons and joints are used for motor activity.

2.8
kinaesthetic, adj
appertaining to kinaesthesis

NOTE 1 Types of kinaesthetic sensation arise from force, movement, position, displacement and joint angle.

NOTE 2 Types of kinaesthetic actions include movement, exertion of force and torque, and achievement of position, displacement and joint angle.

NOTE 3 *Proprioception* refers to the sense of one's own body position and movement. This term is often used interchangeably with kinaesthesis, although the latter is concerned more with motion. The sense of balance, for example, might fall more under proprioception than kinaesthesis.

2.9
force feedback
force presented to and detected by a user

NOTE Although this does not necessarily involve *feedback*, the term “force feedback” is commonly used in this context.

2.10
perceptual illusion
perception that does not correspond to a physical measurement of the stimulus source

2.11
sensory adaptation
change over time in the responsiveness of the sensory system to a constant stimulus

2.12
(tactile/haptic) spatial masking
effect that occurs when a distracter stimulus, which is close to the target stimulus, degrades the perception of the target

2.13
(tactile/haptic) temporal masking
effect that occurs when a distracter stimulus, which is presented immediately preceding or following a target stimulus, degrades the perception of the target

2.14
tactile/haptic object
component of an interactive system that a user can interact with haptically

2.15
(tactile/haptic) user interface element
entity of a user interface that is presented in a tactile/haptic form

2.16
(tactile/haptic) task primitive
fundamental action of a user for carrying out the tasks for which the device is designed

2.17
tactile label
label of a user interface element that is presented in the tactile/haptic modality

2.18
tactile map
map that is presented in the tactile/haptic modality with input functions

NOTE 1 The input functions include finger touching, lifting off, or moving across the map for producing position and selection.

NOTE 2 Tactile maps are often used to help blind people navigate.

2.19
stiffness
hardness
elasticity
haptic response to interactions involving force normal to a virtual object's surface

NOTE 1 “Stiffness” is often known as “hardness” when applied to rigid material.

NOTE 2 “Stiffness” is often known as “elasticity” when applied to soft material.

NOTE 3 *Maximum stiffness* is the highest equivalent spring constant of a virtual surface that can be provided by the device without instability.

2.20
burst
intentionally short tactile/haptic stimulation

NOTE A burst typically lasts between 10 ms and 1 s.

2.21
probe
object in a virtual space that is under the control of a tactile/haptic device

2.22
spatial resolution
degree to which the physical output from a user can be utilized by the device

2.23
addressability
ability to address a specific point or set of points in a workspace

3 Introduction to haptics

The science of haptics and the creation of tactile/haptic devices depend on knowledge of the human body, especially on its capability to sense both touch to the skin and kinaesthetic activity in the limbs and body joints.

Figure 1 shows the relationship between the components that make up the field of haptics. The field is divided between the study of touch and the study of kinaesthesis.

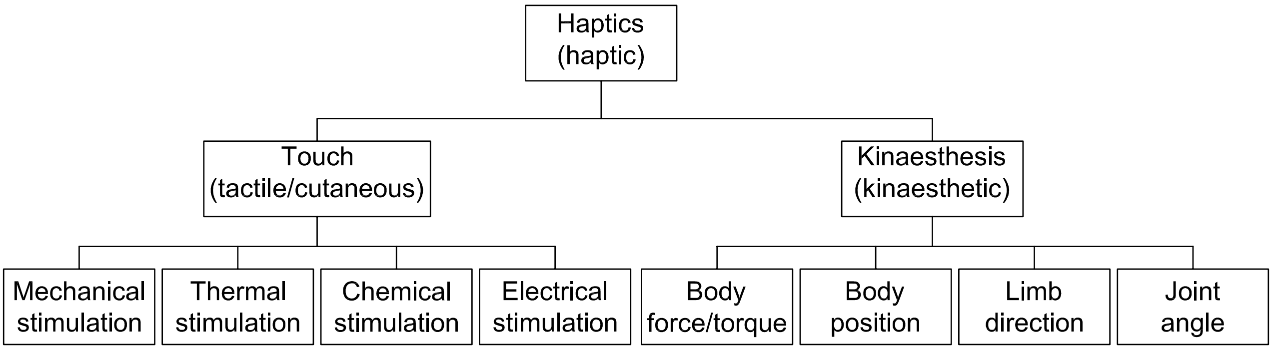

Figure 1 — The components of haptics

“Touch” includes such diverse stimuli as mechanical, thermal, chemical and electrical stimulation to the skin. Specific nerves and sensing organs in the skin respond to these stimuli with different spatial and temporal resolutions.

The *kinaesthetic* sense can be matched by kinaesthetic activity by which a user exerts force or torque on an object external to the active body part. With the combination of kinaesthetic sensing and kinaesthetic activity, the user can detect the force and torque with which the body resists the force and torque of a tactile/haptic device. Likewise, by imposing a measured force and torque on an object, the user can determine macro properties such as its inertia.

Kinaesthesis is thereby bi-directional, both sensing the environment and actively manipulating it in a two-way exchange of information and action.

NOTE 1 Active touch involves kinaesthesis, passive touch does not. Active and passive touch are often very useful concepts by which to distinguish interactions. In interactions, it is not always possible to identify the two concepts with particular devices. Depending on the task, one form of touch might be superior to another.

NOTE 2 Interaction with tactile/haptic devices might use different combinations of these haptic components at multiple points of contact.

NOTE 3 See Annex C for the details of the physiology of human haptics.

4 Human haptic exploration

4.1 Importance of the haptic sense

Haptics is of great importance for human life, much more so than is generally recognized. For instance, when you are searching for an object in your pocket or bag without the help of vision, haptics is engaged. When you identify the object you wanted, grasp it with suitable force and take it out, your actions are based on haptics. This sense can identify common objects quite efficiently, with near perfect discrimination within a few seconds, especially when the observer has some expectation about the options.

By palpating the surface of a body, a physician can obtain information about the conditions of organs under the skin and fat layers, conditions that cannot be perceived visually.

The haptic sense can also allow remote touching, as when a distant object is probed with a tool. For example, a visually impaired person may use a cane to perceive the properties of the ground at the tip of the cane.

The hands, in particular, have had an enormous importance in the biological and cultural development of human beings in their contact with the environment. They are at the same time useful for both perception and action in a continuous interaction with the environment. A hand has an impressive ability to adapt to many different kinds of manipulation tasks, from very small ones requiring high precision to large ones where large forces are needed. The actions are at all times guided by haptic feedback.

However, haptics within computer applications is new compared to visual and auditory interactions and is still relatively limited. Present-day tactile/haptic devices still need much development before they can fully utilize the capacity of the haptic sense.

Touch is also often used to confirm information we gain about the reality of the world.

4.2 Haptics and vision

4.2.1 Similarities and differences between haptics and vision

Haptics has many properties in common with vision. It can be used to locate objects in relation to the observer in near space (but only within arm's reach unless a tool is used), to find edges separating surfaces and to perceive the size and form of objects (that are not too large to be explored by a person). In perceiving texture, haptics not only matches vision but is, in many conditions, superior to it.

In some tasks, haptics lags considerably behind vision or cannot perform the task at all. For example, it is unable to be used to get an overview of a scene, perceive 3D space beyond arm's reach, perceive colours, or perceive edges in a 2D picture without embossment.

In other tasks, haptics is superior to vision. With haptics, we can directly judge the weight of objects, as well as their hardness and temperature. Vision can to some extent perceive such object properties, but only by observing another person's actions.

4.2.2 Co-location of visual and haptic space

In the real world, objects are usually perceived to occupy the same location visually and tactually but, in virtual worlds, this is not necessarily the case. The visual object can be located on a screen, while the haptic object has another location — presented on a tactile/haptic device by the side of the keyboard, for example. Advantages of co-location have been shown for object targeting and for perception of form. Informally, it has also been found that performing tasks such as finding knobs and regaining contact with lost virtual objects was facilitated under co-location conditions.

Combining the visual and haptic modalities can enrich a user's perception of a scene. The visual sense might dominate at first, allowing a quick overview of a scene and identification of objects in the scene. But a tactile display can allow a more rapid judgment of the texture of an object. The relative distances of objects can be perceived haptically within personal space, reinforcing visual judgment of the distances. Then object properties such as mass and deformability can be confirmed only through the haptic sense.

EXAMPLE A pianist, when sight-reading music, relies on haptics to locate the position of the notes on the keyboard, but, while playing from memory, utilizes visual and haptic modalities together, making the performance more relaxed and thus enriching it.

4.2.3 Implications for haptic displays

The differences between vision and haptics make it hazardous to simply render copies of visual objects in order to present them haptically. Such copying might succeed in simple cases, but problems will often occur in more complex ones. It is important that the creation of effective haptic scenes involves the haptic consideration of their properties. An effective visual rendering of a scene is no guarantee that the same scene can be successfully rendered in a haptic sense.

Advantage can be taken of the ability of the body to quickly coordinate cross-modal maps of its environment. Both visual and tactile senses can work together to allow a more rapid location of a stimulus than is possible with either modality alone.

Other prediction experiments have shown that dynamic tactile information can be used to reorient visual attention, and that dynamic visual information can be used to accurately reorient tactile information.

4.3 Manual exploration of objects

The movements of an observer during haptic exploration of the environment are typically not random, but are specifically directed to acquire desired information. These movement patterns, called exploratory procedures, consist of a number of basic procedures such as

a) lateral motion for perceiving texture,

b) pressure for perceiving hardness,

c) unsupported holding for perceiving weight,

d) enclosure (enclosing an object in a hand or both hands) for perceiving global shape and volume, and

e) contour-following for perceiving global shape and exact shape.

Tactile/haptic devices might limit the exploratory procedures that are available to a user, significantly decreasing exploratory performance. Special training in the movements useful for specific displays can partially compensate for this lack.

4.4 Training in exploratory procedures

Texture is less of a problem for the perception of objects than is shape. This might be because the exploratory procedure for texture is much simpler than that for shape. When exploring for texture, the user might make arbitrary movements over the object's surface, while exploring for shape requires quite specific movements. However, training in appropriate exploratory procedures for a given shape can result in much better performance. This is important to consider when evaluating haptic displays, as there is a risk of under-estimating the usefulness of a device if the users have insufficient experience with the device.

4.5 The problem of getting an overview of a scene with haptics

One of the most difficult problems with haptics in many practical contexts is gaining an overview of a scene. In vision, this overview is carried out almost instantaneously. There are situations where a "haptic glance" (short contact with the object) can provide something of the same quality as vision, especially when the observer has hypotheses about the object in question. However, it is usually a laborious and time-consuming task to identify objects in more complex conditions using haptics alone. It is often useful to enhance haptics with auditory or visual information. For instance, there could be verbal or textual information about the object, or instructions about how to explore the scene.

4.6 Minimum physical stimulation: absolute thresholds

Haptic perception is based on many kinds of sensors in the skin, as well as in the muscles, tendons and joints. A minimum of physical stimulation, called *absolute threshold*, is needed to get the sensors to react and send messages providing experience for the observer. Many physical events can stimulate the skin, from a light brush stroke to pressure from points, edges, corners and curvature. They might cause skin motion, skin stretch or vibration, and require different amounts of energy to be perceived. The spatial acuity of the skin has been found to be around 1 mm. In general, the hand is not as good in spatial discrimination as the eye but is better than the ear. With regards to temporal discrimination, the hand is better than the eye, but poorer at it than the ear.

The skin is a large sense organ and its different parts vary in sensitivity. The fingertips are among the most sensitive parts and best suited to exploring the environment. The lips and the mouth are also very sensitive. This particular sensitivity has recently been utilized by the development of a tactile/haptic device that is to be placed in the mouth. Less sensitive parts of the body, such as the stomach and back, have also been used as locations for tactile/haptic devices, but spatial resolution in these locations is much lower than in the hands and mouth.

It is important to consider the age of potential users of tactile/haptic devices, since there is a considerable decline in haptic sensitivity with age.

4.7 Minimum differences needed for perception

A minimum of physical difference between two stimulations is necessary for an observer to experience the difference. This is called the difference threshold or "just noticeable difference" (JND).

EXAMPLE 1 In discerning the difference in the direction of two forces, the difference is at least 33° in order for the difference to be detected.

EXAMPLE 2 In comparing objects by squeezing them, the resistance force in one is about 7 % larger than in the other in order for the difference to be detected.

4.8 Perception of geometric properties of objects

Object properties can be divided into geometric and material properties. Size and shape are geometric properties commonly used for the identification of objects. In the real world, the exploratory procedures of enclosure and contour-following are used to gain this information. These procedures are not always possible with current haptic displays. Perception of shape is possible with such displays but is less efficient and more time-consuming than in the real world. One key reason for this is that most tactile/haptic devices offer a single point of contact.

4.9 Perception of weight

Haptic perception of weight has been studied since the nineteenth century. Such studies recently took a new direction in considering how people judge weight on the basis of wielding the object to be judged. The stimulation in this case is the resistance to the rotational torque picked up by the haptic system. Properties such as the length of a rod or the form of an object can be judged by wielding the rod or object. The amount of liquid in an opaque container can be judged by haptics alone when the container is shaken.