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Spatial orientation and direction of movement — Ergonomic requirements

Orientation spatiale et sens du mouvement — Exigences ergonomiques

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 1503 was prepared by Technical Committee ISO/TC 159, *Ergonomics*, Subcommittee SC 4, *Ergonomics of human-system interaction*.

This second edition cancels and replaces the first edition (ISO 1503:1977), which has been technically revised.

Introduction

It is essential for the safety and usability of any system or product that the relationship between the direction of its controls intended by a user/operator and the resulting direction of movement of the target object be standardized.

For example, if the operation of fire-fighting equipment is not standardized, then swift and appropriate operation in the event of a fire is difficult. If a one-hand lever is to be moved forward in Model A and backward in Model B for speed-up of a railway electric car, frequent human error and, eventually, accidents are likely to be caused. If a computer does not respond in accordance with what is shown on its screen, then its usability and the efficiency of its user/operator will suffer. In construction work, effectiveness, efficiency and user/operator satisfaction will be diminished if the user/operator's intention to make a dynamic change of the target object is not well followed in the control of earth-moving machinery.

One of the purposes of this International Standard is to contribute to the enhancement of safety by preventing human error during use as well as maintenance of a system and/or product. Another is to improve effectiveness, efficiency and user/operator satisfaction by making the change of state and/or the movements of a target object consistent with the user/operator's intention.

The first edition of ISO 1503 was constructed mainly in the framework of geometry regarding the definition of three dimensional axes, geometrical orientation and the direction of control and display movements. This revised edition incorporates the ergonomic issues that affect direction design with the aim of making the standard more directly applicable in real-world situations. It deals with ergonomics design principles and requirements for direction for products and work systems in a combined way — both for conventional technical systems and newly developed information technology-related systems.

Spatial orientation and direction of movement — Ergonomic requirements

1 Scope

This International Standard sets out design principles, procedures, requirements and recommendations for the spatial orientation and direction of movement of controls and displays used in tool machines, industrial robots, office machines, earth-moving machinery, transportation (automobiles, railway electric cars/rolling stock, aircraft, ships, etc.), information, daily commodities, public utilities and the operational components of building facilities.

It lays down basic requirements for determining the operating direction of controls and the moving directions or changing states of the target object, as well as other relations.

This International Standard

— defines three dimensional axes, the observer, viewing systems, linear movement, rotary movement, two-dimensional and three-dimensional movements in a dynamic space sequentially,

— describes the four principles for determining the operating direction of a control, the moving direction of a target object and/or display,

— provides GUI (graphical user interface) design requirements and recommendations that integrate the relationship between the computer operation and the movement of images on-screen in line with human characteristics and to promote safety and efficiency in computer-assisted tasks,

— sets out design principles and recommendations for determining the moving directions of a target object and the controls of a combined control system using a multi-direction control that easily realizes the complex operations intended by the user/operator as they are often seen in industrial apparatuses for business use, and

— gives principles and recommendations for the direction design of existing, as well as new, systems.

NOTE Ergonomics requirements or recommendations given in this International Standard can also be applied to designing the direction of movement of other industrial goods, such as medical equipment, TV or PC game devices and relevant machines/devices.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 6385:2004, *Ergonomic principles in the design of work systems*

ISO 9241-110, *Ergonomics of human-system interaction — Part 110: Dialogue principles*

ISO 9355-2:1999, *Ergonomic requirements for the design of displays and control actuators — Part 2: Displays*

ISO 9355-4, *Ergonomic requirements for the design of displays and control actuators — Part 4: Location and arrangement of displays and control actuators* [1)]

ISO 13407:1999, *Human-centred design processes for interactive systems*

3 Terms and definitions

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

3.1
axis
one of three assumed infinite mutually perpendicular straight lines through the centre point of the target object

NOTE The infinite straight lines run from behind to front, from left to right, and from top to bottom, corresponding to the longitudinal axis, X, transverse axis, Y and normal axis, Z, respectively (based on the Cartesian system of coordinates).

3.2
centre point
assumed reference point for the spatial orientation and determination of movements of a target object

NOTE The centre point is the primary standard provided by the intersecting point of three axes or three reference planes. This point corresponds to the viewpoint of the **observer** (3.10) in the **internal viewing system** (3.20.2), and can be located anywhere on the target object according to the purpose of observation in the **external viewing system** (3.20.1). The centre point need not coincide with the gravitational centre of the target object.

3.3
mono-direction control
single-direction control
one or a set of controls that control the movements of a target object only on one axis at a time

3.4
multi-direction control
control unit that alone can control a target object in two or more moving directions along X, Y and Z axes and in the planes composed of these axes or in the space composed of three planes

3.5
combined control system
control system in which two or more **multi-direction controls** (3.4) are applied

NOTE This system is seen typically in modern earth-moving machinery.

3.6
direction
position of a point in space relative to another point, independent of the distance between the two points

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1) To be published.

3.7
human-centred design
user-centred design
design approach that is characterized by the active involvement of users, a clear understanding of user and task requirements, an appropriate allocation of function between users and technology, iterations of design solutions, and multi-disciplinary design

NOTE 1 See ISO 13407:1999, 5.1, for its principles.

NOTE 2 Usability engineering is often used as a substitute for human-centred design. But, applying usability engineering methods does not necessarily prescribe the active user involvement that is the essence of human-centred design. In addition, usability engineering often over-emphasizes the role of evaluation methods. Human-centred design, on the other hand, refers to the process of analyzing context of use, eliciting user requirements, producing design solutions and evaluating the design against the requirements — all in an iterative fashion.

3.8
clockwise, adv, adj
right-hand rotation
direction of a rotary movement of a target object to the right when viewed in direction X

3.9
anticlockwise GB, adv, adj
counter-clockwise US, adv, adj
left-hand rotation
direction opposite to **clockwise** (3.8) (right-hand) rotation

3.10
observer
real or hypothetical person who views a target object from outside or inside of it when determining the direction or movement of a **target object** (3.14)

3.11
user
individual interacting with the system

[ISO 13407]

3.12
operator
person given the task of installing, operating, adjusting, maintaining, cleaning, repairing or transporting machinery or a system

NOTE Within the context of this International Standard, the tasks performed concern the control of equipment or devices.

3.13
reference plane
one of three perpendicular planes passing through the centre point of a **target object** (3.15) which, in each case, contains two axes of the target object

NOTE The planes that contain longitudinal axis X and transverse axis Y, longitudinal axis X and normal axis Z, and transverse axis Y and normal axis Z are called the basic plane, Pxy, longitudinal plane, Pxz, and transverse plane, Pyz, respectively.

3.14
spatial orientation
direction-related inherent property of a **target object** (3.15)

NOTE Spatial orientation of a target object is characterized by pairs such as front-behind, right-left or up-down.

3.15
target object
object (including images) whose **spatial orientation** (3.14) or movements are to be defined, established or controlled

3.16
usability
extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use

[ISO 9241-11]

NOTE 1 See Annex A.

NOTE 2 For the purposes of this International Standard, **user** (3.11) is interchangeable with **operator** (3.12) for those activities that involve movement of controls or target objects.

3.16.1
effectiveness
accuracy and completeness with which users achieve specified goals

[ISO 9241-11]

NOTE For the purposes of this International Standard, **user** (3.11) is interchangeable with **operator** (3.12) for those activities that involve movement of controls or target objects.

EXAMPLE The percentage of attained goals.

3.16.2
efficiency
resources expended in relation to the accuracy and completeness with which users achieve goals

[ISO 9241-11]

NOTE For the purposes of this International Standard, **user** (3.11) is interchangeable with **operator** (3.12) for those activities that involve movement of controls or target objects.

EXAMPLE The time needed to complete a task.

3.16.3
satisfaction
freedom from discomfort and positive attitudes towards the use of the product

[ISO 9241-11]

EXAMPLE The frequency of willingness to use.

3.16.4
context of use
users (3.11) or **operators** (3.12), tasks, equipment (hardware, software, and materials) and the physical and social environments by, with or in which, a product is used

3.17
user interface
UI
man-machine interface
MMI
human-machine interface
HMI
human-system interface
HSI
component of an interactive system (software or hardware) that provides the information and controls necessary for the user to accomplish specific tasks with the interactive system

NOTE Adapted from ISO 9241-110.

3.18
viewing direction
assumed direction to which an **observer** (3.10) looks, when determining the **direction** (3.6) of a **target object** (3.14)

3.18.1
viewing direction X(E)
viewing direction from the front side of a **target object** (3.15) toward the **centre point** (3.2) along the longitudinal **axis** (3.1) in the **external viewing system** (3.19.1)

NOTE See Annex B.

3.18.2
viewing direction X(I)
viewing direction from the **centre point** (3.2) of a **target object** (3.15) toward the front side along the longitudinal **axis** (3.1) in the **internal viewing system** (3.20.2)

NOTE See Annex B.

3.18.3
viewing direction Y
viewing direction along the transverse axis, Y, to the right

NOTE See Annex B.

3.18.4
viewing direction Z
viewing direction along the normal axis, Z, below

NOTE See Annex B.

3.19
viewing point
position of an **observer's** (3.10) eye

3.20
viewing system
system in which position, posture and **viewing direction** (3.18) of the **observer** (3.10) are fixed with reference to the three axes of the **target object** (3.15) in order to render possible its **spatial orientation** (3.13) and determination of its directions of movement

3.20.1
external viewing system
EVS
viewing system in which the location of the **observer** (3.10) is assumed to be outside the **target object** (3.15)

NOTE See Annex B.

3.20.2
internal viewing system
IVS
viewing system in which the location of the **observer** (3.10) is assumed to be inside the **target object** (3.15)

NOTE See Annex B.

4 Design of spatial orientation and direction of movement

4.1 General

This clause relates to direction design: basic ergonomics recommendations for user interfaces (4.2), the ergonomics steps for direction design (4.3), individual ergonomics requirements and recommendations for human-machine interfaces (4.4), and graphical user interface (4.5) and combined control (4.6) design recommendations.

Detailed requirements for spatial orientation and direction of movements are given in Annex B.

4.2 Ergonomic design of user interface (UI) with respect to orientation and direction

The ergonomic design of a UI includes

— anthropometric aspects (e.g. body size, hand reach envelopes, visual field),

— cognitive aspects (e.g. compatibility of information displays/controls, human error tolerance),

— physiological capability aspects in information processing (e.g. workload, information processing speed, accuracy), and

— environmental aspects (e.g. illumination, colour, noise).

UI design should be human-centred. Since the design of orientation and direction of movement of a target object is a crucial component of UI design, the displays and controls and their relationship should be easy to understand and use. The UI should be designed taking into account safety, usability and human characteristics (sensing, sensitive intention, perception, human communication, etc.).

Human-centred design features the following essential conditions (see ISO 13407 and Annex C):

a) a clear understanding of the requirements/constraints of the user/operator and the task in question through the user's/operator's active involvement;

b) an appropriate allocation of function between the user/operator and the machine for the accomplishment of the task;

c) frequent review of the design based on feedback from the user/operator;

d) collaboration among team members throughout the process.

4.3 Steps in direction design

Major goals of direction design are to ensure safety, efficiency, ease of use and comfort. The designer's first undertaking is to clarify the main goals of the direction design of the controls/displays within systems design. Safety should be given a high priority, among multiple goals, in the design. Direction of movement design is accomplished through specifying the task in question, determining the user(s)/operator(s) and determining the relative priorities of safety, efficiency, ease of use and comfort.

Direction of movement design includes the following steps.

a) Define the task and function.

b) Specify the user/operator in accordance with ISO 13407.

c) Specify the task in terms of

   1) the movements/displays of the target object and controls to perform the task,

   2) relative priorities in conducting the task (safety, efficiency, ease of use or comfort),

   3) user's/operator's working posture in performing the task,

   4) work space where the task is performed,

   5) the flow of information for conducting the task, and

   6) environmental factors (e.g. ambient illumination, necessity of protective clothes).

d) Define movements/displays of the target object and location of the controls.

   1) Specify an area as a specific layered zone, corresponding to the view area and the frequency and priority of the controls used within the area, in accordance with ISO 9355-2:1999, Figures 1 and 2.

   2) Specify the location of the displays and controls, according to priority of function in the task, in accordance with ISO 9355-2:1999, 4.1 and ISO 9355-4, 4.3.

   3) Specify the arrangement of the displays and the controls in accordance with ISO 9355-4, 4.4.

4.4 Design requirements/recommendations for human-machine interface (HMI)

4.4.1 General

When designing an HMI, designers shall determine the operating directions of the controls and movements of the target object considering ergonomic design principles in accordance with ISO 6385:2004, 3.6.5, while taking into account the population stereotype. In case a stereotype does not exist, either the mental model or metaphor may be taken into account.

NOTE “Population stereotype” is a natural human sense with respect to the directions of movement and operations (see Reference [6]). For example, drivers expect that a car will turn right if they turn the steering wheel to the right, and when learning how to drive they are trained to use the brake as a knee-jerk reaction — which is how stereotypes are formed.

When arranging two or more displays units and controls, attention shall be paid to their directional consistency. The following is also recommended.

a) Displays and controls should function in a manner to reduce the probability of human errors.

b) Displays should be selected, designed and laid out in a manner compatible with the characteristics of human perception and the task to be performed.

c) Controls should be selected, designed and laid out in such a way as to be compatible with the characteristics (particularly of movement) of that part of the body by which they are to be operated and the task to be performed. Skill, accuracy, speed and strength and dexterity requirements should be taken into account.

d) Controls should be selected and arranged, where possible, within the constraints of the space available to suit the target population stereotype, sequence and movement of controls.

e) Controls should be selected and laid out in a manner compatible with the dynamics of the control process and its spatial representation.

f) Controls should be close enough to facilitate correct operation where they are to be operated simultaneously or in quick succession. However, they should not be so close as to create a risk of inadvertent operation.

Figure 1 shows the framework of a direct boundary formed functionally and morphologically between the user/operator and real-world target objects.

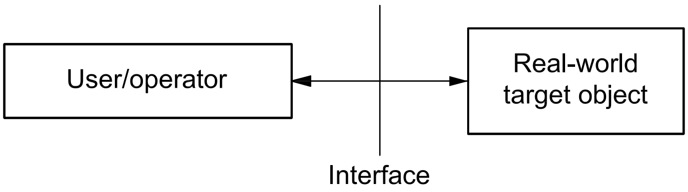


Figure 1 — Conceptual model of human-machine interface

4.4.2 Operating directions of controls

4.4.2.1 Coordination between operation and movement

When designing a display/control interface, the operating direction of controls shall be compatible with the intended movement of the target object.

EXAMPLE 1 The linear movement of a target object to the right corresponds to pushing a lever to the right.

EXAMPLE 2 The clockwise rotary movement of a target object results from turning a hand-wheel clockwise.

However, in some cases, stereotypes of the user/operator population contradict this natural relationship and different solutions may be required.

EXAMPLE 3 Movement of a small boat's tiller is opposite to the direction in which the boat turns in response.

4.4.2.2 Coordination between similar controls

In order to achieve the same or similar movements or changes among target objects, regardless of whether the target objects are of similar or different types, controls of the same or similar types shall be operated in the same direction.

4.4.2.3 Coordination with different controls

When technical reasons demand that different target objects undergo the same movement or change using different controls, the movements of the controls and the resulting changes in the target objects shall be compatible with the series of pair concepts given in Table 1 and consistent within each column, Group A or B.

Table 1 — Pairs of terms for the coordination between controls and the target object

	Group A	Group B
Position	Left, port	Right, starboard
	Below	Above
	Down	Up
	Bottom	Top
	Behind: EVS on side turned from observer IVS in the stern; at end	Front EVS on side turned to observer IVS in the bow; at the nose
	End	Beginning
Direction of movement	To the left	To the right
	Downward	Upward
	Towards the user/operator	Away from the user/operator
	Anticlockwise rotation	Clockwise rotation
	Backward: EVS to user's/operator's viewing direction IVS opposite to user/operator's viewing direction	Forward: EVS opposite to user's/ operator's viewing direction IVS to user's/operator's viewing direction
Condition	Dark	Light
	Cold	Warm
	Soft, quiet	Loud
	Slow	Fast
	Minus (−)	Plus (+)
	Decelerate (brake)	Accelerate
	To reduce effects (e.g. brightness, speed, power, pressure, temperature, voltage, current, frequency, luminous intensity)	To increase effects (e.g. brightness, speed, power, pressure, temperature, voltage, current, frequency, luminous intensity)
Action	To switch off	To switch on
	To open an electric circuit	To close an electric circuit
	To put out of service	To put into service
	To stop	To start, to go
	To release	To fasten, to engage
	To close a valve	To open a valve
	To extinguish	To ignite
	To empty	To fill
	To pull	To push, to depress
	To uninstall	To install
	To download	To upload
	To scroll down	To scroll up

4.4.2.4 Change of controls

Even when the operating direction of the conventional controls is not compatible with the requirements of 4.4.2.2 and 4.4.2.3, designers shall not reverse the conventional operating direction in order to meet the requirement; instead, the mode of the controls shall be changed to ensure the essential safety as follows.

a) If the clockwise rotation of the hand-wheel results in the anticlockwise movement of a machine part, the anticlockwise rotation of the hand-wheel shall not subsequently cause an anticlockwise movement of the machine part. The hand-wheel may be replaced by a lever or push buttons whose control movements meet the requirements of 4.4.2.1 and 4.4.2.2.

b) If the lifting of a lever in a motor vehicle causes the left flashing indicator to light, lowering the lever shall not cause the left indicator to light at any future point. However, the lever may be set at right angles or replaced by push buttons or a rotating control element in order to meet the requirements of 4.4.2.1 and 4.4.2.2.

c) If a lever cannot be used, linear movement of the target object to the right shall be achieved by turning a hand-wheel clockwise, or by operating the right-hand button of two corresponding push buttons.

4.4.2.5 Markings

The controls shall have markings, such as clear symbols or characters: symbols are preferable because they are generally easier to understand.

4.4.3 Movement of target object and operating direction of controls

The relation between the target object movement and operating direction of controls shall be determined as follows.

a) Direction of movement of linear controls (see ISO 9355-4):

- switches and levers on a vertical panel are directed upward for ON/increase and downward for OFF/decrease;

- switches and levers on a lateral (horizontal) panel are directed forward (away from the user/operator) for ON/increase and backward (toward the user/operator) for OFF/decrease.

b) Direction of rotary movement of controls:

- controls are turned clockwise for ON/increase and anticlockwise for OFF/decrease.

NOTE Nevertheless, the stereotype can contradict this because of the mechanical design used for the control. For example, flow control valves are typically rotated anticlockwise to increase the flow due to the fact that, when rotated in the reverse direction, they screw in to shut off the flow.

4.4.4 Direction of target object movement and operating direction and location of controls

4.4.4.1 Target object moves in same direction as controls

When the target object moves linearly, the controls should move linearly.

When the target object rotates, the controls should rotate.

However, if stereotypes indicate a direction of movement contrary to the natural direction specified above, consider tilting the control surface up or down to compensate.

EXAMPLE If a lever control moves backwards for moving the target object forwards, tilt the control surface down so that the backwards movement of the control is toward the upward direction at the same time.

4.4.4.2 Target moves linearly and controls rotate

When the target object moves linearly and the controls rotate, the controls should be placed below or on the right of an indicator, if any, showing the movement of the target object.

4.4.4.3 Target rotates and controls move linearly

When the target object rotates and the controls move linearly, unless the target object is hidden behind the controls during operation, the controls should be placed below or on the right of any indicator, showing the movement of the target object.

4.4.4.4 Biomechanical forces

When a user/operator is inside a moving target object, biomechanical forces can affect the recommended location and direction of movement of controls. In such cases, biomechanical force effects should be considered, which could result in a design that differs from that specified in this International Standard.

EXAMPLE In a railway operation, the dynamic acceleration effect on the operator's whole body induced by an operational action might cause unintended effects on subsequent operations due to unnatural working posture.

4.4.5 Arrangement of two or more displays and controls

In cases when two or more displays or controls are arranged side by side and required to be positioned in a certain sequence, they should be arranged as described in ISO 9355-4:—, 4.4.1.5. However, it is important to consider the direction of movement of both displays and controls when arranging them, taking into consideration their functional relationships.

4.5 Design recommendations for graphical user interfaces (GUI)

4.5.1 General

The following subclauses provide design recommendations related to direction-setting in a situation in which a user/operator interacts with a target object in the virtual or real world via a GUI, which typically includes a graphic display, pointing device and keyboard, employing information and communications technology (ICT). It does not cover situations in which the user/operator directly (or sometimes remotely) interacts with a real-world object mainly via physical manipulation devices.

4.5.2 Direct control interaction with virtual objects and indirect control interaction with real-world objects

It needs to be noted that the distinction between a), b) and c), as follows, might not always be clear. For example, the user/operator interacting with a driving simulator intended for driving practice could have a real-world car as specified in type b) or even c) in mind, while a driving simulator intended for use in development or testing can provide interaction as a virtual target object of type a). Electronic documents are generally understood as being virtual objects that provide interaction of type a), but for user's/operators highly experienced in environments in which high-precision display equipment and high-speed printers can be used, they could be taken as type b) or even type c) interaction tools, through which it is possible to work with an image of real-world paper documents in mind.

a) Direct interaction with a virtual target object

The user/operator directly interacts with, and controls, a virtual object implemented through ICT. Virtual objects may include purely logical or abstract control objects that do not correspond to real-world target objects. See Figure 2.

EXAMPLE 1 Viewing objects in a virtual museum using a virtual reality modelling language (VRML) viewer.

EXAMPLE 2 Searching/exploring/navigating in a huge information space (such as a large-scale website).

EXAMPLE 3 Operating a driving or flight simulator.

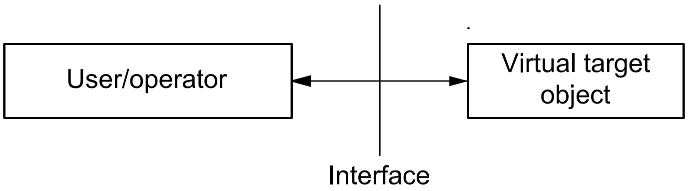


Figure 2 — Conceptual representation of direct control interaction with virtual target object

b) Indirect control interaction for real-world objects

The user/operator interacts with a displayed representation of a real-world target object via ICT. See Figure 3.

EXAMPLE 1 The shutdown of a computer using a dialogue box on the display screen.

EXAMPLE 2 A web monitoring camera in which the viewing directions can be changed up, down, left or right using software controls such as knobs and sliders of the form within the web page.

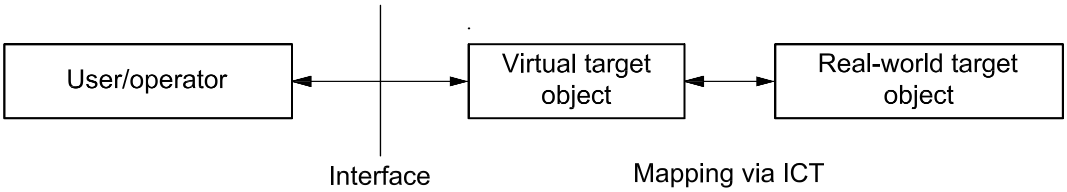


Figure 3 — Conceptual representation of indirect interaction with real-world target object

c) Direct interaction with real-world target object using information from virtual target object

The user/operator directly interacts with, and controls, a real-world target object using the information from the virtual target object generated in a display space via ICT. See Figure 4.

EXAMPLE 1 Surgery performed by a surgeon looking at the display of a diseased organ via visualization technology such as an endoscope or an ultrasonic computed tomography (CT).

EXAMPLE 2 Driving an automobile in reverse while looking at a rear-view camera or a monitor.

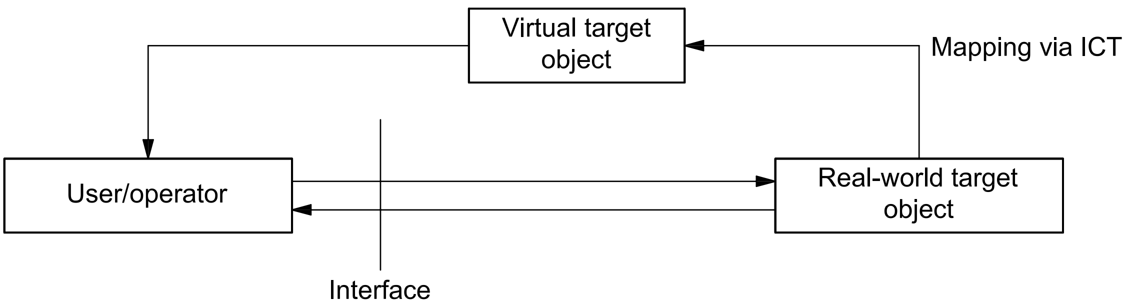


Figure 4 — Conceptual representation of direct interaction with a real-world target object using information from virtual target object

4.5.3 Dialogue principles

For the application of dialogue principles in design, ISO 9241-110 shall be consulted.

4.5.4 Design of virtual target object

4.5.4.1 General

The following subclauses (4.5.4.2 to 4.5.4.10) give recommendations that are specific to orientation and direction design where the user/operator engages in interaction with a virtual target object in a GUI type environment. Most of these recommendations apply to the three interaction types described in 4.5.2, but where a provision applies only to one of these types, it is so indicated.

4.5.4.2 Correlation of a virtual target object to a real-world target object

Mapping of real-world target objects into virtual target objects should directly correspond to the information necessary to perform the task.

NOTE It is desirable that virtual objects be made to resemble, or to be analogous to, real-world objects, in aspects such as their appearance and functions, from the perspective of making use of the user's/operator's experiences and raising situation awareness.

NOTE Making a virtual target object similar or analogous to a familiar real-world target object is also important for the same reasons, even for those cases where there is no corresponding real-world target object.

Where purely logical or virtual target objects lacking corresponding or comparable real-world target objects are used, such as complex numbers and negative resistance, supporting means such as on-line help or guided tours should be made available to help the user/operator manipulate such objects without difficulty.

4.5.4.3 Presentation of environmental information

Presentation of environmental or surrounding information should be compatible with the user's/operator's recognition. Such information should be considered in the design of virtual object space to enhance the user's/operator's situation awareness and to support his or her situation judgment and decision making.

4.5.4.4 Reduced dimensionality

The display space (display screen) through which the user/operator interacts with the virtual target object is typically a two-dimensional space. When a real-world three-dimensional object space is presented in such a two-dimensional space using some projection techniques, loss of some information is unavoidable. The following is recommended in order to prevent or limit negative consequences of such loss of information.

a) The axis that has the smallest effects on the task performance should be used as the longitudinal axis in the projected space.

b) If all three axes are of equal importance in performing the task, spatial correspondence to the real-world control may be sacrificed and an abstract or idealized virtual space should be considered.

c) If insufficiency of depth perception arises (even if three-dimensional display technology is available), countermeasures should be taken to cover such insufficiency.

4.5.4.5 Display capacity

The amount of information that can be presented by a display screen used as a virtual object space is insufficient for expressing a real-world object space with sufficient fidelity. Relative to this, the following is recommended in the design of a virtual object space.

a) Where the amount of information that has to be displayed is far greater than the display device capacity, software techniques such as fine-coarse display, fish-eye display, bird's eye views and display scrolling should be used — but only to the extent that they do not introduce unacceptably large distortions in the display of the information, thus affecting the task performance.

b) Abstraction and idealization of information should be used to the extent that the real-world object space information necessary to carrying out the task is preserved.

NOTE 1 A fine-coarse display is a technique which shows a specific area of concern, in a map for example, in detail, sometimes making the periphery opaque

NOTE 2 A fish-eye display is, like a picture taken using a fish-eye lens, used to show a wide area around the user/operator, with the focal area shown in detail and the periphery roughly.

NOTE 3 A bird's eye view is a three-dimensional scene, looked down on as if from altitude and covering a wide area.

4.5.4.6 Perceptual modality

Display devices used as virtual object space are usually limited to conveying visual and auditory information. Olfactory and other perceptual information (surrounding information), including smells, vibration and tilting, cannot be generally conveyed to the user/operator. Relative to this, the following is recommended in the design of a virtual object space.

a) If sufficient display capacity is available, presentation of environmental information such as odour and vibration, utilizing appropriate information visualization techniques, should be considered.

b) The use of haptic and tactile devices to convey surrounding information should be considered.

4.5.4.7 Frame of reference

When a virtual object space (display screen) is placed and viewed within the user's/operator's field of vision, the display frame and its surrounding environment should serve as a frame of reference through which the viewed object is recognized. The movement of an object or several objects in the display frame in one direction can induce the perception of movement of the display frame or viewer in the opposite direction. Care should be taken in the design of the virtual target object space such that the frame of reference does not cause unintended effects of motion perception or motion sickness that adversely affect task performance for which the object space is intended.

4.5.4.8 Manipulation of an object and viewing point

In accordance with the needs of the task, functions for manipulating the target object and/or functions for manipulating the viewing point should be provided: the former corresponds to IVS (internal viewing system) and the latter to EVS (external viewing system) in the case of real-world target objects. The means of employing these functions should be easily distinguishable, especially where both functions are provided, in which case the methods of employing similar functions (such as moving the target object forward and moving the viewing point forward) should be consistent. Whether the target object or the viewing point is moved forward, it should be distinguishable to the user/operator.

4.5.4.9 Direction of notation in logical or abstract quantities [4.5.2 type c) interface]

While this International Standard deals with spatial orientation and direction of movement, this subclause provides recommendations for displaying direction of logical or abstract quantities within the relation to direction of control. It is concerned with the direction of notation of additive quantities, sequential quantities, hierarchy structures, time and relations between the directions of displays and controls. Descriptions of the horizontal orientation are related to the orientation in which the language used is written. Only languages that are written from left to right are considered.

a) Additive quantities

Additive quantities (e.g. mass, length, numbers of items and prices) are also referred to simply as quantities or values on the interval scale. Summation or subtraction between their values makes sense.

Additive quantities from lesser to greater should be displayed as follows:

— from left to right where a horizontal orientation is used;

— from bottom to top where a vertical orientation is used;

— clockwise rotation where a rotational orientation is used.

NOTE The category of additive quantities includes conceptual or abstract quantities such as complex numbers and negative resistance.

EXAMPLE

(1) Horizontal	**(2) Vertical**	**(3) Rotational**
10 20 30	300	1
	200	2
	100	3
		4

b) Sequential quantities

Sequential quantities [e.g. months (January, February …), forms (1st form, 2nd form …)] are also referred-to values on the ordinal scale. These quantities have their rank in an order of precedence and can be placed sequentially in that order.

Sequential quantities should be displayed in the following order of precedence:

1) from left to right where a horizontal orientation is used;

2) from top to bottom where a vertical orientation is used;

3) clockwise rotation where a rotational orientation is used.

EXAMPLE

(1) Horizontal	**(2) Vertical**	**(3) Rotational**
1st 2nd 3rd	1st	1st
	2nd	2nd
	3rd	3rd
	4th	4th

NOTE 1 The real-word physical arrangement of the information (e.g. building floors) could require the order of display of the information (e.g. elevator display) to be in the same order as the physical order.

NOTE 2 It is important to maintain consistency in the use of sequencing in an application domain.

NOTE 3 The sequencing strategy of elements can differ depending on customs, preferences, etc. For example, school forms may be sequenced as “1st form”, “2nd form” and “3rd form” and the transmission gears of an automobile as “Low”, “2nd”, “3rd” and “Top”, or vice versa.

NOTE 4 Where not only a display, but also a control (in this case, the operation of selection), is incorporated, relative distances from the initial or starting point of the choice action become involved, and it is appropriate to place items higher in the ordering scheme closer to the starting point.

c) Dynamic value displays

If the information is displayed dynamically (for a given point in time) in a single window, in order to increase the value the control should indicate “up” (e.g. upward arrow) to increase and “down” (e.g. downward arrow) to decrease.

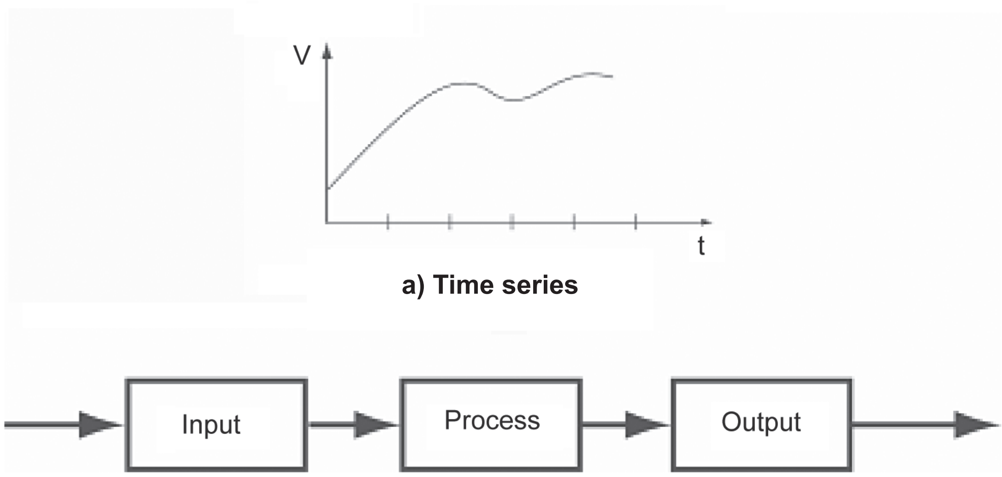
NOTE In cases where the direction of change is important, it is useful to show direction of movement in addition to the value (e.g. a directional arrow).

d) Hierarchical structures (tree structure)

A hierarchical structure expressed in the shape of a tree should take the top level as the highest part of the representation, and parts of lower levels should be placed at lower portions of the representation. When elements on the same level stand in an ordered relation to each other, their placement should conform to the recommendation in b), above, concerning the horizontal orientation of sequential quantities.

e) Time

When time is displayed (in a virtual target object space), it is desirable to display it following the principles described in b), above, for sequential quantities, as a set of quantities standing in relations of precedence (earlier and later) to each other. In time series graphs and process charts, it is generally desirable to take the horizontal for the time axis and to place events that happened earlier to the left of events that happened later. See Figure 5 for an example.



a) Time series

b) Process chart/flow chart

Figure 5 — Direction of notation — Examples of time display

4.5.4.10 Relations between the direction of displays and controls

The relationship between the direction of movement of displayed objects and the movement of associated controls should be as given in Table 2.

Table 2 — Recommended relations between direction of displayed objects and control movements

Control direction	Display direction					
	Horizontal		Vertical		Rotational	
	Quantities					
	Additive	**Sequential**	**Additive**	**Sequential**	**Additive**	**Sequential**
Horizontal →	Recommended	Conditionally recommended	Acceptable	Conditionally acceptable	Acceptable	Not acceptable
Horizontal ←	Not acceptable	Conditionally recommended	Not acceptable	Conditionally acceptable	Not acceptable	Not acceptable
Vertical ↑	Acceptable	Conditionally acceptable	Recommended	Conditionally recommended	Not acceptable	Conditionally acceptable
Vertical ↓	Not acceptable	Conditionally acceptable	Not acceptable	Recommended	Acceptable	Acceptable
Rotational ↷	Acceptable	Conditionally acceptable	Not acceptable	Conditionally acceptable	Recommended	Recommended
Rotational ↶	Not acceptable	Conditionally acceptable	Conditionally acceptable	Not acceptable	Not acceptable	Conditionally recommended
In “Conditionally acceptable” and “Conditionally recommended”, *conditionally* means that inconsistency between the arrangement direction of a displayed element and the direction of control is dissolved in the user's/operator's mental process or because of a real physical relationship.						

4.6 Design recommendations for combined control systems

4.6.1 General

Systems that simultaneously control more than one movement in modern industrial equipment, such as combined arm-boom-bucket operation and turn operation by hydraulic excavators in construction work, are collectively called *combined control systems*.

Employment of a combined control system can improve the quality and efficiency of machines equipped with moving and working functions; examples of this are common among earth-moving and agricultural machinery, industrial remote manipulators and medical instruments. There are two types of control system: mono-direction (single-direction simultaneous) and multi-directional.

The following is recommended for the design of combined control systems using both hands and/or both feet and the direction of the resulting movement of the target object.

a) Relationships between controls and movements

1) The operating direction of each multi-directional control should correspond to the movement direction of the target object.

2) The overall movement direction of the target object should correspond to the user's/operator's mental model of the task when he or she operates a combined control system.

3) Relationship consistency shall be maintained throughout the progress of a task.

b) Posture and muscle load

1) The user's/operator's basic operating posture should not be unnaturally changed by a combined control system.

2) Muscles should be used economically and specific arm/leg muscles should not be used intensively so that the overall load on muscles is within a reasonable range.

c) Effects of skill and experiences

1) Due consideration should be given so that acquired skills and experiences will also be useful in other control units of a similar operating mode.

2) Direction design should take into account control units of other related machines.

5 Conformance

5.1 Applying requirements and recommendations

The individual requirements and recommendations given in Clause 4 are evaluated for their applicability and, if judged applicable, implemented, unless there is evidence that to do so would cause deviation from the design objectives. The checklist given in Annex D can be used for this purpose.

5.2 Evaluation of products

If a product is claimed to have met the applicable requirements/recommendations in this International Standard, the procedure used for evaluating the product shall be specified and documented. The details of the specification of the procedure are a matter of negotiation between the involved parties.

Annex A
(informative)

Constituent factors of usability

Usability is composed of goal of use, context of use and result of use in regard to product use, as shown in Figure A.1 (see also ISO 9241-11).

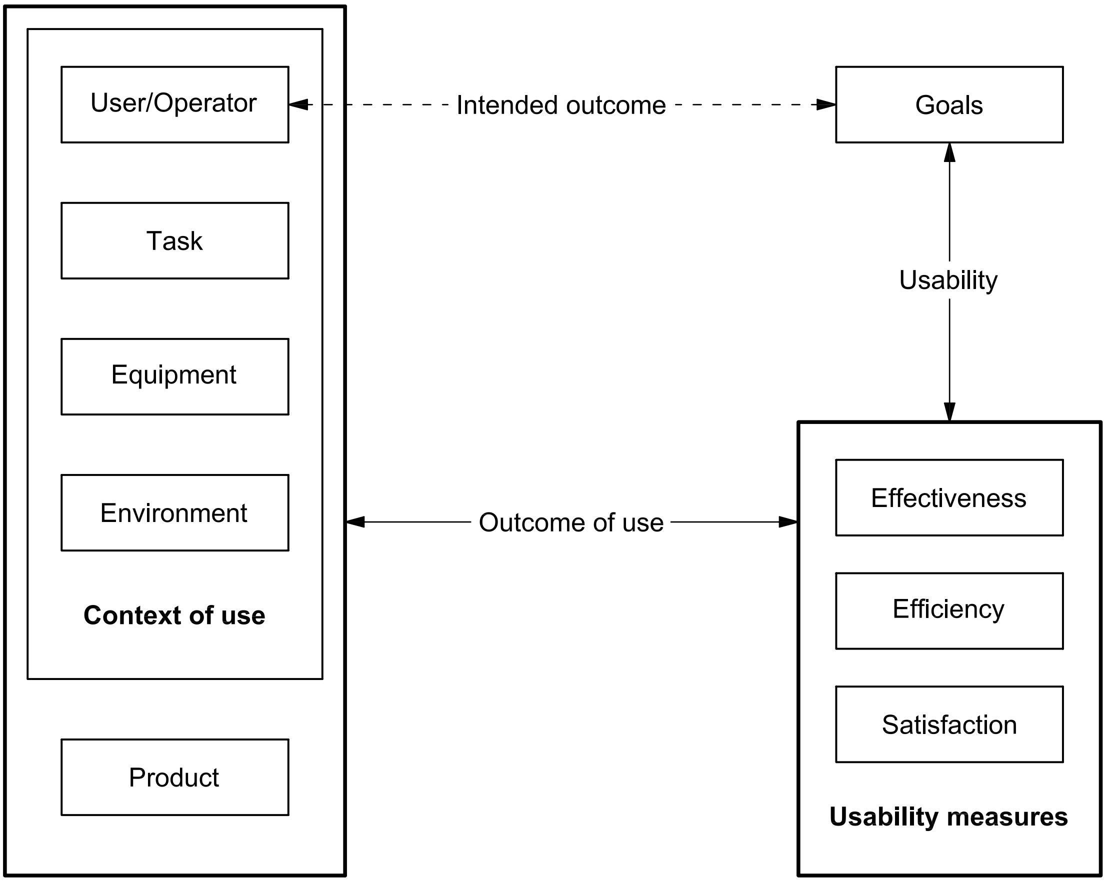


Figure A.1 — Usability

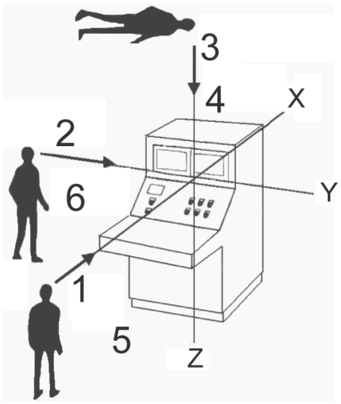
Annex B
(normative)

Reference model for spatial orientation and direction of movement

B.1 Viewing systems

B.1.1 Location and viewing direction

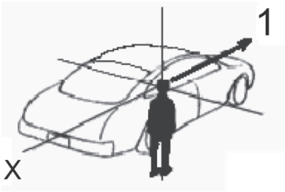
Location and viewing direction are placed on one of the three axes, and viewing direction X is initially determined according to the property of the target object and purpose of observation (see Figures B.1 and B.2). For the external viewing system (EVS), the location of the observer is assumed to be in front of the target object, with the observer standing/sitting straight up before the target object, looking at the target object in viewing direction X. For the internal viewing system (IVS), it is assumed that the location of the observer is at the centre point of the target object, with the observer standing/sitting straight up, looking at the target object from the centre point to the front side along viewing direction X.



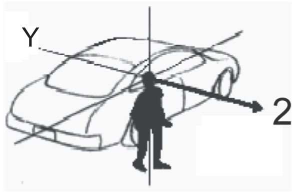
Key

1 viewing direction X
2 viewing direction Y
3 viewing direction Z
4 above
5 front
6 left

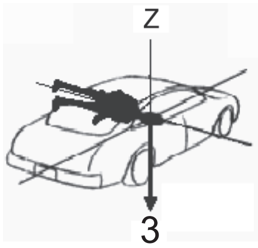
Figure B.1 — Determination of direction X, Y and Z by EVS



Viewing direction X



Viewing direction Y



Viewing direction Z

Key

1 front
2 right
3 below

Figure B.2 — Determination of directions X, Y and Z by IVS

B.1.2 Choice of viewing system

Either EVS or IVS shall be adopted according to the characteristics of the target object and purpose of viewing.

NOTE Adjacent target objects or related parts are frequently assigned to different viewing systems. For example, a motor vehicle is assigned to the internal viewing system, while the instruments on its dashboard are assigned to the external viewing system.

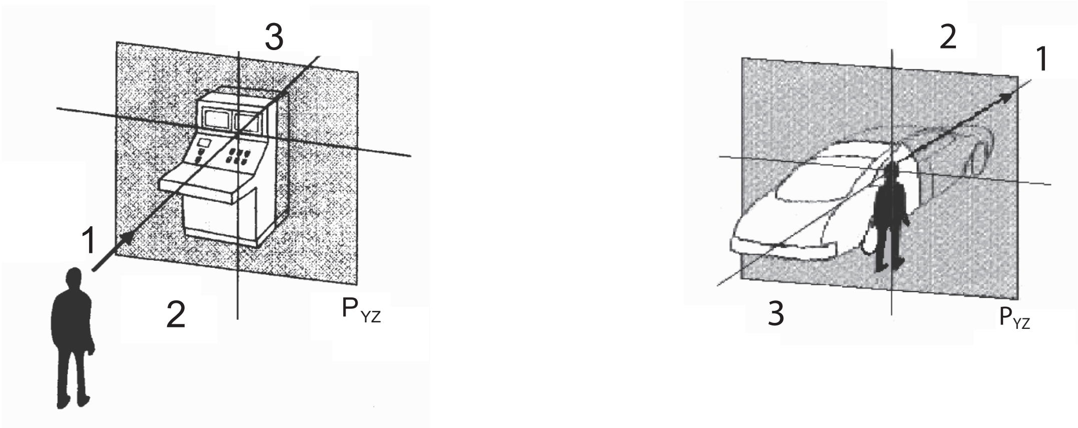
B.2 Concepts of three-dimensional orientation of the target object

B.2.1 In-front–behind pair concept

The concept of the pair, in-front–behind, is based on the following.

— In EVS: the position of all points that lie between the transverse plane, Pyz, and the observer are considered to lie on the *in-front* side; the position of all points that lie on the far side of the transverse plane, Pyz, from the observer are considered to lie on the *behind* side. See Figure B.3 a) for an example.

— In IVS: the position of all points that lie in viewing direction X from the transverse plane, Pyz, are considered to lie on the *in-front* side; the points which lie contrary to the viewing direction, X, from the transverse plane, Pyz, are considered to lie on the *behind* side. See Figure B.3 b) for an example.



a) EVS b) IVS

Key

1 viewing direction X

2 front

3 behind

Figure B.3 — In-front–behind pair concept — Examples

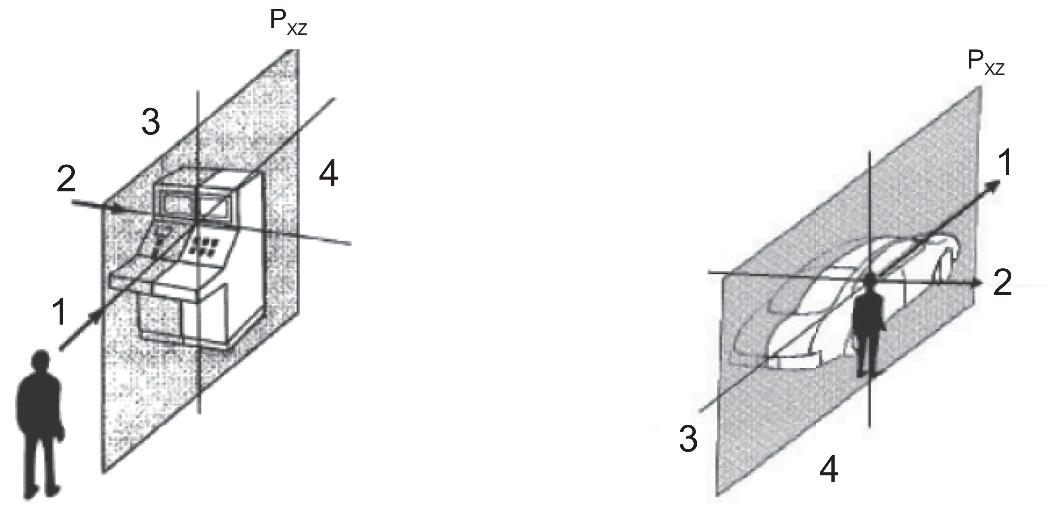
B.2.2 Right–left pair concept

The concept of the pair, right–left, common to both EVS and IVS, is based on the following.

— The position of all points that lie on the right side of the longitudinal plane, Pxz, when viewed along the X axis in the Pxz plane are considered to lie on the *right* side.

— The position of all points that lie on the left side of the longitudinal plane, Pxz, when viewed along the X axis in the Pxz plane are considered to lie on the *left* side.

See Figure B.4 for examples.



a) EVS **b) IVS**

Key

1 viewing direction X
2 viewing direction Y
3 left
4 right

Figure B.4 — Right–left concept — Examples

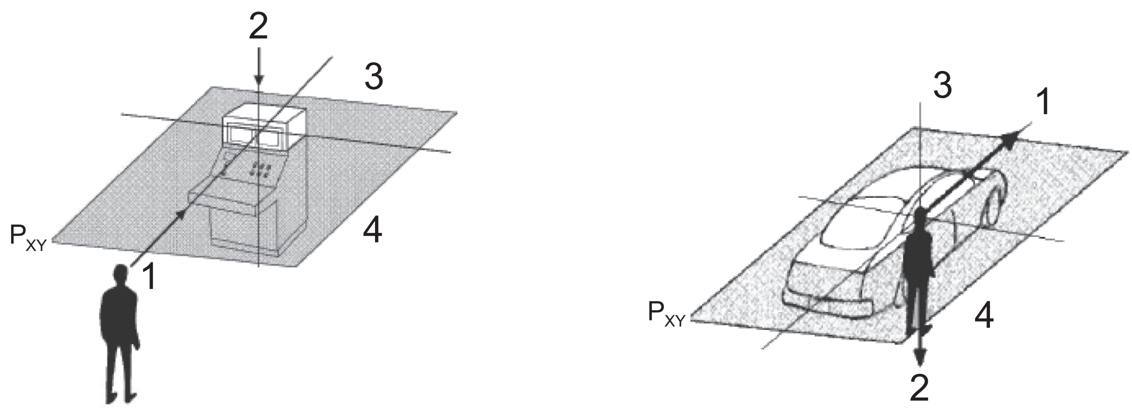
B.2.3 Up–down pair concept

The concept of the pair, up–down, common to both EVS and IVS, is based on the following.

— The position of all points that lie above the basic plane, Pxy, when viewed along the X or Y axis in the Pxy plane are considered to lie on the *up/above* side.

— The position of all points that lie below the basic plane, Pxy, when viewed along the X or Y axis in the Pxy plane are considered to lie on the *down/below* side.

See Figure B.5 for examples.



a) EVS **b) IVS**

Key

1 viewing direction X
2 viewing direction Z
3 above
4 below

Figure B.5 — Above–below concept — Examples

B.3 Directional concepts for linear movement

B.3.1 Forward–backward pair concept

The concept of the pair, forward–backward, is based on the following.

— For EVS: any movement parallel to the longitudinal axis, X, contrary to viewing direction X is *forward* movement; any movement parallel to the longitudinal axis, X, in viewing direction X is *backward* movement. See Figure B.6 a).

— For IVS: any movement parallel to the longitudinal axis, X, in viewing direction X is *forward* movement; any movement parallel to the longitudinal axis, X, contrary to viewing direction X is *backward* movement. See Figure B.6 b).

NOTE The term *movement* in the sense of “direction of movement of control” defines an act by the user/operator that causes linear movement, rotary movement, circular movement or screw motion of a control so as to attain the desired control effect.

a) EVS **b) IVS**

Key

1 viewing direction X

2 forward

3 backward

Figure B.6 — Forward–backward pair concept — Examples

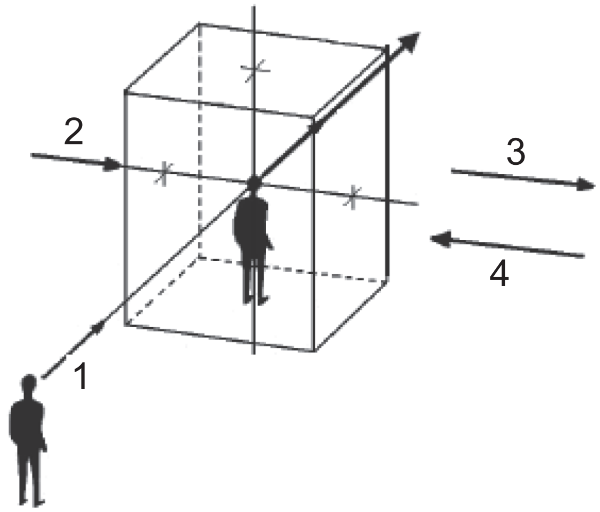
B.3.2 Right-to-left pair concept

The concept of the pair, right-to-left, common to both EVS and IVS, is based on the following.

— Any movement parallel to the transverse axis, Y, contrary to viewing direction Y is movement to the *left*.

— Any movement parallel to the transverse axis, Y, in viewing direction Y is movement to the *right.*

See Figure B.7.



Key

1 viewing direction X
2 viewing direction Y
3 to the right
4 to the left

Figure B.7 — Right-to-left pair concept

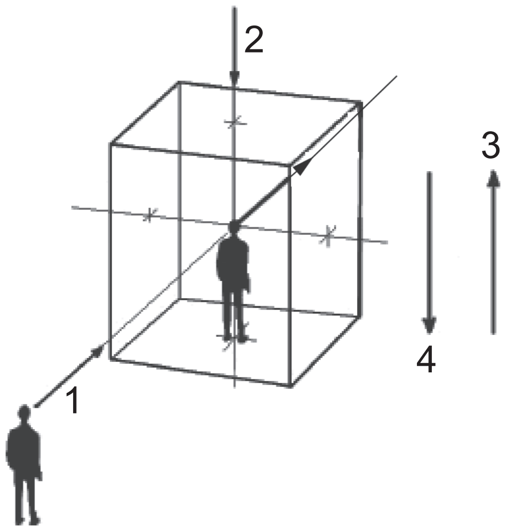
B.3.3 Upward–downward pair concept

The concept of the pair, upward–downward, common to both EVS and IVS, is based on the following.

— Any movement parallel to the normal axis, Z, contrary to viewing direction Z, is upward movement.

— Any movement parallel to the normal axis, Z, in viewing direction Z is downward movement.

See Figure B.8.



Key

1 viewing direction X
2 viewing direction Z
3 upward
4 downward

Figure B.8 — Upward–downward pair concept

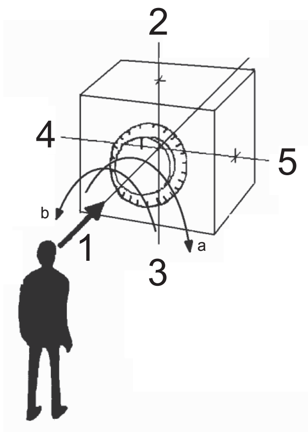
B.4 Directional concepts for rotary movement

B.4.1 Viewing direction in rotary movement

In determining all rotary movements, it is assumed that the imaginary viewing direction of the observer, irrespective of his or her actual location and viewing direction, coincides with the axis about which the target object or its parts rotate.

B.4.2 Rotation about longitudinal axis, X

When seen in viewing direction X, rotation to the right about the longitudinal axis, X, is clockwise; rotation in the opposite direction is anticlockwise. See Figure B.9.



Key

1 viewing direction X

2 above

3 below

4 left

5 right

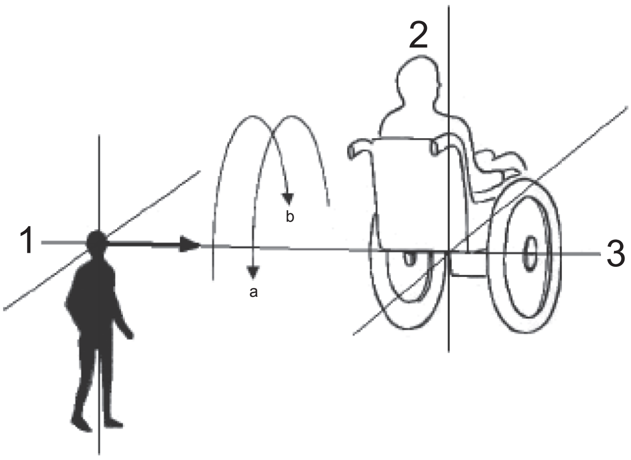
a Clockwise rotation.

b Anticlockwise rotation.

Figure B.9 — Clockwise and anticlockwise rotation about longitudinal axis, X

B.4.3 Rotation about transverse axis, Y

When seen in viewing direction Y, rotation to the right about the transverse axis, Y, is clockwise; rotation in the opposite direction is anticlockwise. See Figure B.10.



Key

1 viewing direction Y

2 user/operator

3 rotation axis

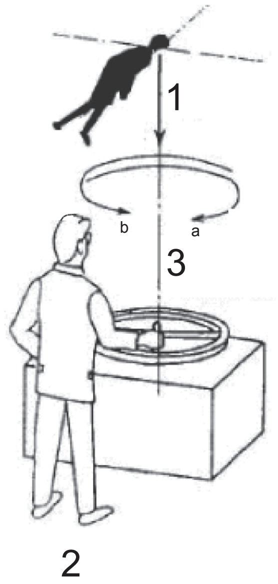
a Clockwise rotation.

b Anticlockwise rotation.

Figure B.10 — Clockwise and anticlockwise rotation about transverse axis, Y

B.4.4 Rotation about normal axis, Z

When seen in viewing direction Z, rotation to the right about the normal axis, Z, is clockwise; rotation in the opposite direction is anticlockwise. See Figure B.11.



Key

1 viewing direction Z

2 user/operator

3 rotation axis

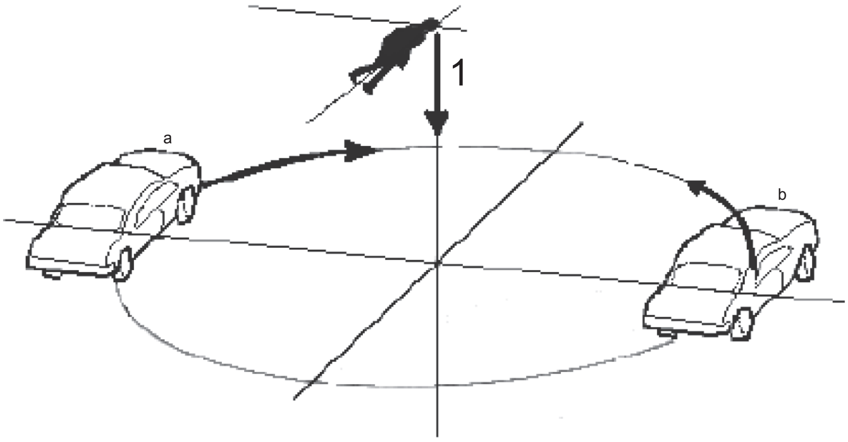
[a] Clockwise rotation.

[b] Anticlockwise rotation.

Figure B.11 — Clockwise and anticlockwise rotation about the normal axis, Z

B.5 Directional concept for circular movement

When the observer views along an axis passing through the centre of the circle, circular movements of the target object in the clockwise direction are called clockwise circular movements; circular movements in the anticlockwise direction are called anticlockwise circular movements. See Figure B.12 for an example.



Key

1 viewing direction Z

a Clockwise circular movement.

b Anticlockwise circular movement.

Figure B.12 — Clockwise and anticlockwise circular movement about normal axis, Z — Example

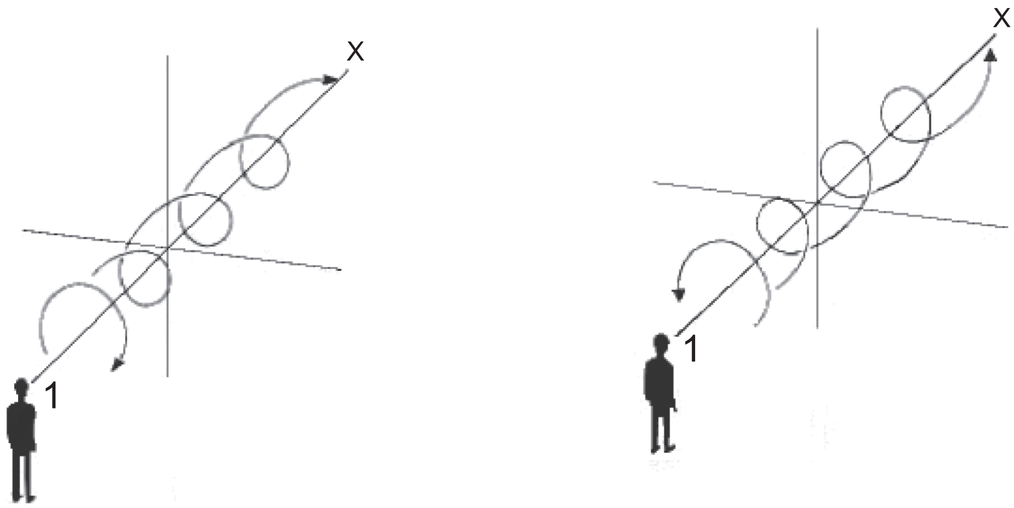
B.6 Directional concepts of screw motion

B.6.1 Viewing system for screw motion

When determining the direction of screw motion, IVS is always used regardless of actual location and viewing direction of the observer.

B.6.2 Direction of screw motion

Linear movement in the viewing direction of the observer, combined with a simultaneous rotation to the right is *clockwise* screw motion; the linear movement combined with a simultaneous rotation to the left is *anticlockwise* screw motion. See Figure B.13 for an example.



a) Clockwise screw motion

b) Anticlockwise screw motion

Key

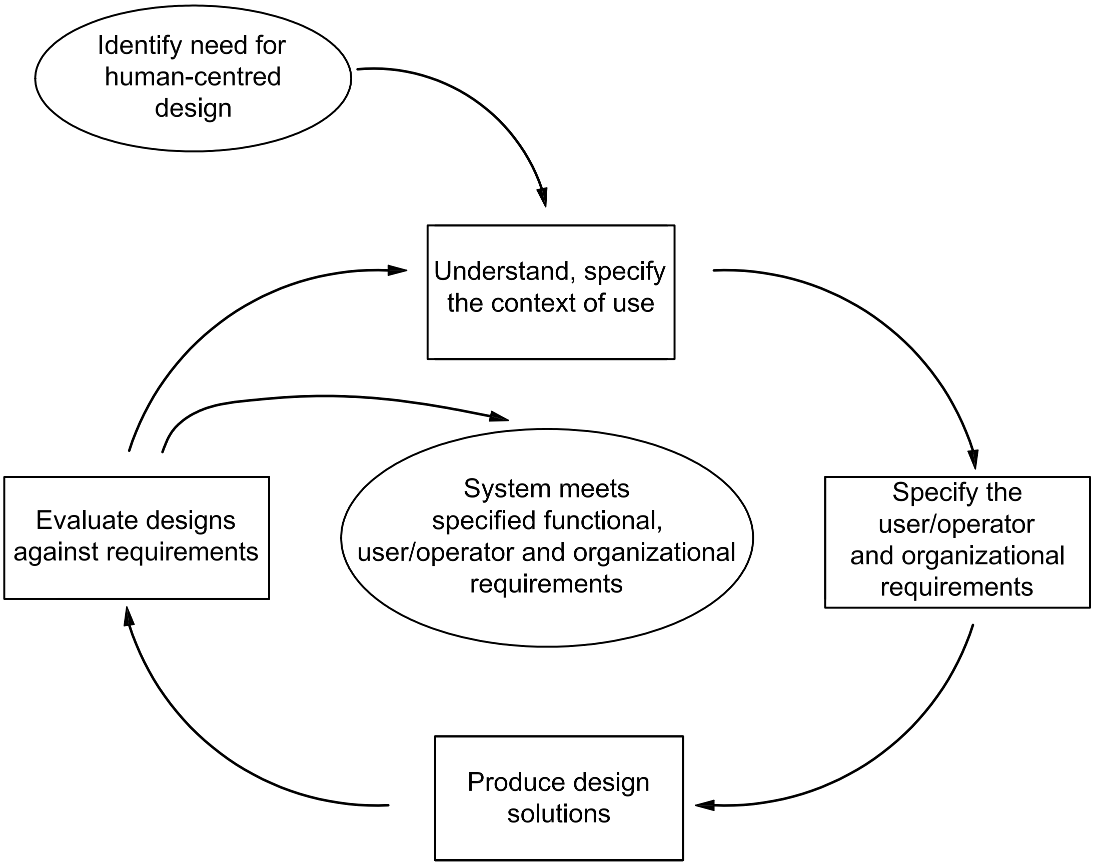
1 viewing direction X

Figure B.13 — Screw motion in viewing direction X about longitudinal axis, X — Example

Annex C
(informative)

Flow of human-centred design activities

The steps for achieving human-centred design are shown in Figure C.1 (see also ISO 13407:1999).



NOTE Designing for direction of movement and spatial orientation involves identification of functional and operational needs, and the identification of the user's/operator's goals, experience, mental models and stereotypes.

Figure C.1 — Flow of human-centred design activities

Annex D
(informative)

Spatial orientation and direction of movement design checklist

Table D.1 presents a checklist of the provisions of this International Standard. When using the checklist, proceed as follows.

a) Define the design product to be checked.

b) For each item, check whether the item is applicable or not, and check whether the design result meets the corresponding requirement ("shall") or recommendation ("should").

c) Enter comments, or list references, to prove that the design product meets the requirement/recommendation.

d) Develop a more detailed checklist in the technical area.

e) The "Requirement/Recommendation" column gives the number and title of the corresponding subclause of this International Standard, together with a précis or description of the relevant provision(s) for convenience of use of the checklist.

   Refer to Clause 4 for the exact requirement, recommendation or other provision.

Table D.1 — Design checklist

Requirement/Recommendation	Applicable? Y/N	Met? Y/N	Comments
4.2 Ergonomic design of user interface (UI) with respect to orientation and direction			
The human-machine interface should be designed taking into account safety, usability and human characteristics (sensing, sensitive intention, perception, human communication, etc.).			
Human-centred design features the following essential conditions (see ISO 13407 and Annex A):			
a) clear understanding of the requirements/constraints of the user/operator and the task in question through the user's/operator's active involvement;			
b) appropriate allocation of function between the user/operator and the machine for the accomplishment of the task;			
c) frequent review of the design based on feedback from the user/operator;			
d) collaboration among team members throughout the process.			

Table D.1 (*continued*)

Requirement/Recommendation	Applicable? Y/N	Met? Y/N	Comments
4.3 Steps in direction design Direction of movement design includes the following steps.			
a) Task and function definition			
b) User/operator specified			
c) Task specified in terms of: 1) movements/displays of the target object and controls to perform the task;			
2) relative priorities in conducting the task: safety, efficiency, ease of use or comfort;			
3) user's/operator's working posture in conducting the task;			
4) work space where the task is performed;			
5) flow of information for conducting the task;			
6) environmental factors (e.g. ambient illumination, user/operator wearing protective clothing).			
d) Movements/displays of the target object and location of the controls defined. 1) An area is specified as a specific layered zone corresponding to the view area and the frequency and priority of the controls used within the area.			
2) Location of the displays and controls is specified according to priority of function in the task.			
3) The arrangement of the displays and the controls is specified; see ISO 9355-4.			
4.4 Design requirements/recommendations for human-machine interface (HMI)			
Signals, displays and controls should function in a manner to reduce the probability of human errors.			
Signals and displays should be selected, designed and laid out in a manner compatible with the characteristics of human perception and the task to be performed.			
Controls should be selected, designed and laid out to be compatible with the characteristics (particularly of movement) of that part of the body by which they are operated and the task performed. Skill, accuracy, speed and strength requirements should be taken into account.			
Controls should be selected and arranged, where possible, within the constraints of the space available to suit the target group's stereotype, sequence and movement of controls.			

Table D.1 (*continued*)

Requirement/Recommendation	Applicable? Y/N	Met? Y/N	Comments
Controls should be selected and laid out in a manner compatible with the population stereotypes, the dynamics of the control process and its spatial representation.			
Controls should be close enough to facilitate correct operation where they are to be operated simultaneously or in quick succession. However, they should not be so close as to create a risk of inadvertent operation.			
4.4.2 Operating directions of controls			
4.4.2.1 Coordination between operation and movement Operation of direction of control shall be compatible with the intended movement of the target object.			
4.4.2.2 Coordination between similar controls Regardless of whether the target objects are of similar or different pattern, they shall be operated in the same manner, using the same or similar controls to make the same movements or changes.			
4.4.2.3 Coordination with different controls When technical reasons demand that different target objects undergo the same movement or change using different controls, the movements of the controls and the resulting changes in the target objects shall be harmonized with a series of pair concepts shown in Table 1 to be consistent in each of the same column of Group A and Group B.			
4.4.2.4 Change of controls Even when the operating direction of the conventional controls does not harmonize with the requirements described in 4.4.2.2 or 4.4.2.3, designers shall not reverse the conventional operating direction to meet the requirement; instead, change the mode of the controls to ensure the essential safety as follows:			
a) If the clockwise rotation of the hand-wheel results in the anticlockwise movement of a machine part, the anticlockwise rotation of the hand-wheel shall not subsequently cause a anticlockwise movement of the machine part. The hand-wheel may be replaced by a lever or push buttons, whose control movements meet the requirements of 4.4.2.1 and 4.4.2.2.			
b) If the lifting of a lever in a motor vehicle causes the left flashing indicator to light, lowering the lever shall not cause the left indicator to light at any future point. However, the lever may be set at right angles or replaced by push buttons or a rotating controls element in order to meet the requirements of 4.4.2.1 and 4.4.2.2.			

Table D.1 (*continued*)

Requirement/Recommendation	Applicable? Y/N	Met? Y/N	Comments
c) If a lever cannot be used, linear movement of the target object to the right shall be achieved by turning a hand-wheel clockwise or operating the right-hand button of two corresponding push buttons.			
4.4.2.5 Markings The controls shall have markings, such as clear symbols or characters; symbols are better than characters because they are generally easier to understand.			
4.4.3 Movement of target object and operating direction of controls The relation between the target object movement and operating direction of controls shall be determined as follows:			
a) Direction of linear movement of linear controls (see ISO 9355-4): — in the switches and levers on a vertical panel, ON/increase is directed upward, while OFF/decrease is directed downward;			
— in the switches and levers on a lateral panel, ON/increase is directed forward (away from the user/operator), while OFF/decrease is directed backward (toward the user/operator).			
b) Direction of a rotary movement of a rotary operation system: — controls turn clockwise for ON/increase and anticlockwise for OFF/decrease.			
4.4.4 Direction of target object movement and operating direction and location of controls			
4.4.4.1 Target object moves in same direction as controls The target object should move in the same direction in which the controls are operated:			
a) when the target object moves linearly, the controls should move linearly, and			
b) when the target object rotates, the controls should rotate.			
4.4.4.2 Target moves linearly and controls rotate When the target object moves linearly and the controls rotate, the controls should be placed below or on the right of an indicator, if any, showing the movement of the target object.			

Table D.1 (*continued*)

Requirement/Recommendation	Applicable? Y/N	Met? Y/N	Comments
4.4.4.3 Target rotates and controls move linearly When the target object rotates and the controls move linearly, unless the target object is hidden behind the controls during operation, the controls should be placed below or on the right of an indicator, if any, showing the movement of the target object.			
4.4.4.4 Biomechanical forces When a user/operator is located inside a moving target object, biomechanical forces can affect the recommended location and direction of movement of controls. In such cases, biomechanical force effects should be considered and may result in a design that differs from the requirements stated in this International Standard.			
4.4.5 Arrangement of two or more displays and controls If two or more displays or controls are arranged side by side and required to be positioned in a certain sequence, they should be arranged as described in ISO 9355-4:—, 4.4.1.5. It is important to consider the direction of movement of both displays and controls when arranging them taking into consideration functional relationships.			
4.5 Design recommendations for graphical user interfaces (GUI)			
4.5.2 Direct control interaction with virtual objects and indirect control interaction with real-world objects a) Direct interaction with a virtual target object b) Indirect control interaction for real-world objects c) Direct interaction with real-world target object using information from virtual target object			
4.5.3 Dialogue principles Dialogue principles are to be applied in the design (see ISO 9241-110).			
4.5.4 Design of virtual target object			
4.5.4.2 Correlation of a virtual target object to a real-world target object Mapping of real-world target objects into virtual target objects should directly correspond to the information necessary for performing the task.			

Table D.1 (*continued*)

Requirement/Recommendation	Applicable? Y/N	Met? Y/N	Comments
4.5.4.3 Presentation of environmental information Presentation of environmental or surrounding information should be compatible with user's/operator's recognition. Such information should be considered in the design of virtual object space to enhance the user's/operator's situation awareness and to support user's/operator's situation judgment and decision making.			
4.5.4.4 Reduced dimensionality The following considerations are recommended in order to prevent or limit negative consequences of such loss of information.			
The axis that has the smallest effects on the task performance should be used as the longitudinal axis in the projected space.			
If all three axes are of equal importance in performing the task, spatial correspondence to the real-world control may be sacrificed and an abstract or idealized virtual space should be considered.			
If insufficiencies of depth perception arise (even if three-dimensional display technology is available), countermeasures should be taken.			
4.5.4.5 Display capacity The following considerations are recommended in the design of a virtual object space.			
Where the amount of information that has to be displayed is far greater than the display capacity of the virtual control object space, software techniques such as fine-coarse display, fish-eye display, bird's eye view, and display scrolling should be used to the extent that they do not introduce unacceptably large distortions in orientation of the information thus affecting the task performance.			
Abstraction and idealization of information should be used to the extent that the real-world object space information necessary to carrying out the task is preserved.			
4.5.4.6 Perceptual modality The following considerations are recommended in the design of a virtual object space.			
If sufficient display capacity is available, presentation of environmental information such as odour and vibration utilizing appropriate information visualization techniques should be considered.			
Using haptic and tactile devices to convey surrounding information should be considered.			

Table D.1 (*continued*)

Requirement/Recommendation	Applicable? Y/N	Met? Y/N	Comments
4.5.4.7 Frame of reference Care should be taken in the design of the virtual target object space that the frame of reference does not cause unintended effects of motion perception or motion sickness that impede task performance for which the object space is intended.			
Manipulation of an object and viewing point In accordance with the needs of the task, functions for manipulating the target object and/or functions for manipulating the viewing point should be provided. The means of employing these functions should be easily distinguishable, especially where both functions are provided. Where both are provided, the methods of employing similar functions (such as moving the target object forward and moving viewing point forward) should be consistent. Whether what is moved forward is the target object or the viewing point should be distinguishable to users/operators.			
4.5.4.9 Direction of notation in logical or abstract quantities [4.5.2 type c) interface] The direction of notation in logical or abstract quantities.			
a) Additive quantities Additive quantities from lesser to greater should be displayed as follows:			
— from left to right where a horizontal orientation is used;			
— from bottom to top where a vertical orientation is used;			
— clockwise rotation where a rotational orientation is used.			
b) Sequential quantities Sequential quantities from the elements of the sequence with higher ranking to elements with lower ranking should be displayed as follows:			
— from left to right where a horizontal orientation is used;			
— from top to bottom where a vertical orientation is used;			
— clockwise rotation where a rotational orientation is used.			
c) Dynamic value displays If information is displayed dynamically (for a given point in time) in a single window, to increase the value the control should indicate up (e.g. upward arrow) to increase and down (e.g. downward arrow) to decrease.			

Table D.1 (*continued*)

Requirement/Recommendation	Applicable? Y/N	Met? Y/N	Comments
d) Hierarchical structures (tree structure) A hierarchical structure expressed in the shape of a tree should take the top level as the highest part of the representation, and parts of lower levels should be placed at lower portions of the representation. When elements on the same level stand in an ordered relation to each other, their placement should conform to the recommendation in b) concerning horizontal orientation of sequential qualities.			
e) Time When time is displayed (in a virtual target object space), it is desirable to display it following the principles described in b) for sequential quantities, as a set of quantities standing in relations of precedence (earlier and later) to each other. In time series graphs and process charts, it is generally desirable to take the horizontal for the time axis and to place events that happened earlier to the left of events that happened later.			
4.5.4.10 Relations between the direction of displays and controls The relationship between the direction of movement of displayed objects and the movement of associated controls should follow the recommendations of Table 2.			
4.6 Design recommendations for combined control systems Recommendations for the design of combined control systems using both hands and/or both feet and the direction of the resulting movement.			
a) Relationships between controls and movements 1) The operating direction of each multi-directional control should correspond to the movement direction of the target object.			
2) The overall movement direction of the target object should correspond with the mental model of the user's/operator's accomplishment of a task when he or she operates two or more multi-directional controls.			
3) Relationship consistency shall be maintained throughout the progress of a task.			
b) Posture and muscle load 1) The user's/operator's basic operating posture should not be unnaturally changed by a combined control system.			

Table D.1 (*continued*)

Requirement/Recommendation	Applicable? Y/N	Met? Y/N	Comments
2) Muscles should be used economically and specific arm/leg muscles should not be used intensively so that the overall load on muscles is within a reasonable range.			
c) Effects of skill and experiences 1) Due consideration should be given so that acquired skills and experiences will also be useful in other control units of a similar operating mode.			
2) Direction design should take into account control units of other related machines.			

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