A Tactile/Haptic Interface Object Reference Model

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ABSTRACT
In this paper, we describe present a reference model for evaluating and designing individual tactile or haptic objects and groups of such objects. This model provides an understanding of the many facets involved in individual and groups of tactile or haptic interaction objects.

Categories and Subject Descriptors
H.5.2 User Interfaces, *Ergonomics, Haptic I/O, Input devices and strategies,* D.2.0 Software Engineering General, *Standards*

General Terms
Human Factors, Standardization

Keywords
Tactile, haptic, interactions, interface object, reference model, standards.

1. INTRODUCTION
User interest in tactile and haptic interaction has grown considerably based on large volumes of recent research. However, developers require more than just user interest, they require guidance on how to successfully design and construct sets of tactile and/or haptic objects.

A reference model can help to standardize the design and construction of tactile or haptic interactions, by ensuring that all relevant aspects of these interactions are taken into consideration. Reference models are increasingly used within user interface design.

Lynch and Meads [1] advocated that user interface reference models should "provide a generic, abstract structure which describes the flow of data between the user and the application, its conversion into information, and the auxiliary support which is needed for an interactive dialogue". Recently reference models have been used to define the major components of accessible icons [2], organizing ergonomic and user interface standards [3], [4], and to evaluate the accessibility of systems [5].

2. ASPECTS OF INTERACTION OBJECTS
Figure 1 (based on Figure 1 from ISO/IEC 19766 [2] also created by this author) presents a high level framework for modeling tactile and haptic objects. It shows that there are four major interacting aspects that need to be considered in design: the *identity* of the object, user-*information attributes* that describe the object, *representation attributes* that are used in rendering the object, and *operations* performed on the object. It also recognizes that these objects are often located and used within a group, rather than just used individually, and therefore involve group level operations.

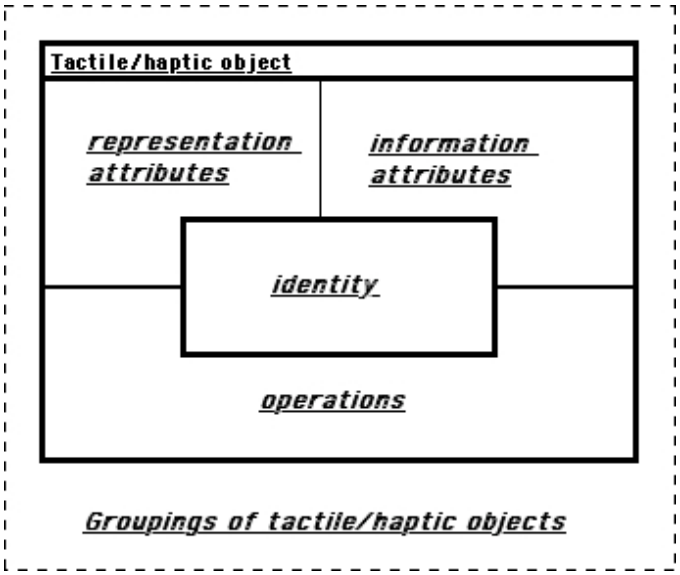

Figure 1. The main aspects of tactile and haptic objects

Figure 2 provides a detailed framework for understanding tactile and haptic objects that expands each aspect (identify, description attributes, representation attributes, and operations) into a number of specific components. This paper discusses each of the components and why it is important for evaluating and designing individual tactile or haptic objects and groups of such objects.

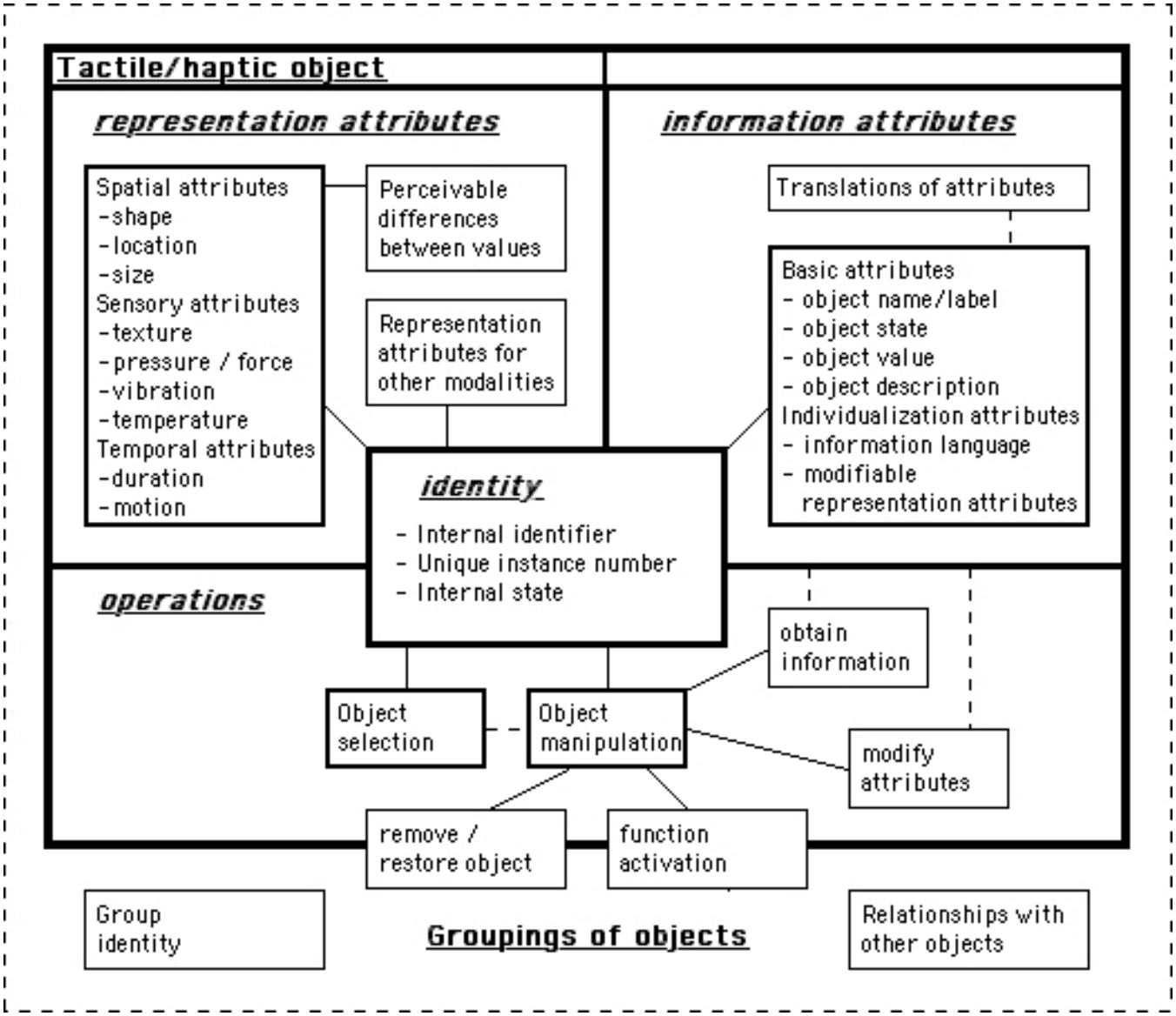

Figure 2. A Tactile/Haptic Interface Object Reference Model

3. OBJECT IDENTITY

All objects in a system require unique identities to provide the controlling software with the ability to recognize and distinguish between objects. They also can support alternate media renderings of an object, including renderings by assistive technologies. These identities are not intended for direct use by end users, who should interact with the other object attributes and operations. Object identities involve both an internal identifier and a state specification.

3.1 Internal Identifier

An internal identifier is a machine readable code that uniquely identifies the functionality that the tactile/haptic object represents. It identifies a class of objects that have either been defined by some international or national standard or that have been defined within an organization or a particular application.

It is expected that GOTHI-05 will start the identification of tactile and haptic interaction objects that are candidates for standardization in order to improve the compatibility of interactions across interfaces, applications, and systems. Use of this reference model will help to ensure that the resulting standards provide sufficient information to ensure the consistent application of these standards across applications. It is further expected that these standards will define unique object (type) identifiers in accordance with ISO 11580 [4] to allow for the automated identification of objects by assistive technologies.

3.2 Unique Instance Number

It is possible for a number of the same type of tactile/haptic objects to be used within an application. Each specific instance of an haptic/tactile object in an application can be identified by a combination of the object's internal identifier and a unique instance number. The instance identifier can be used to distinguish

between multiple instances of the same type of haptic/tactile object within an application.

3.3 State

Many objects behave differently depending on the current state of the object. Recognizing the significance of an object, therefore, requires recognizing both the object and the current state that it is in. Some states of controls include but are not limited to: available, selected, and unavailable. Sub-states may also be relevant, for example: selected and ready for input, selected but read-only. Some states of data containers include but are note limited to: system stored value not available for input; system stored value available for new input; and user entered value not yet stored by system.

An object's state can be based on one or more attributes of the object and/or the environment in which the object occurs. It is expected that future standards for tactile and haptic objects will define applicable object states in accordance with ISO 11580 in a manner that will support the automated identification of the state by assistive technologies.

4. INFORMATION ATTRIBUTES

Information attributes are intended to assist the user in finding out about the object. Information attributes are defined as text attributes so that they can be formatted and presented to the user via the widest possible variety of media / modalities. The basic set of information attributes includes a name/label, an object state, an object value and an object description. Additional information attributes that support individualization of objects can include: the default language that is used for the information attributes, information on the adjustable representational attributes of the object and translations of one or more other information attributes. Depending on the application, some or all of the information attributes of an object may be user modifiable. This is most likely for the object value and some or all of the representational attributes.

4.1 Object Name / Label

Object names / labels are short names that can be used by the user to identify and/or interact with an object. Each name / label needs to be unique within the context in which it is used. NOTE: this is the external, user accessible counterpart to the state that is part of the internal identify. Default object names / labels may be defined in various object information languages. However, it is acceptable for the user and/or the developer to customize an object name / label for use in a specific context of use.

Object labels may be presented as part of the object, on demand to supplement the object, or on their own in place of the object. Where labels are presented, users and assistive technologies should be able to use the label for interaction in a manner that is similar to interacting with the main object. The presentation and use of labels should be consistent for all tactile/haptic objects within a group.

4.2 Object State

All objects, regardless of whether they are controls or data containers have states. (Data containers are either able to be used for input or not.) Information about the state of an object is the first component of an object value. The value of the state is not directly user modifiable, since it results from the object's reaction to various other user operations. NOTE: this is the external, user accessible counterpart to the state that is part of the object identify and can be generated automatically from it.

4.3 Object Value

Tactile/haptic objects that contain data have an object value that is a textual representation (or equivalent) of the data they contain. Because not all objects contain data, information about the value of the data contained is the second (and optional) component of an object value.

4.4 Object Description

Object descriptions are textual information that is presented on demand to provide further elaboration on the purpose and/or use of a tactile/haptic object. The specific contents of descriptions may very between applications. Standardized tactile/haptic objects should have standardized descriptions that will be included in, but need not be the entirety of, the object description used by an application.

4.5 Object Information Language

The object information language is the default natural language used for storing and presenting information attributes. This provides a basis for understanding and translating information attributes. Different objects can be presented in different languages, where appropriate.

Changes to the object information language used to present the object value of a tactile/haptic object should not change the actual internal representation of that data but only be used to facilitate its translation.

Object information language only applies to the language used for textual representation of information attributes. Any language(s) involved in the encoding via shape of the object are dealt with as part of the spatial representation attribute dealing with the object's shape.

ISO 639-2 [10] describes a three-character code set identifying approximately 400 individual languages.

4.6 Modifiable Representation Attributes

The main purpose of representation attributes (as discussed below) is to convey information about the identity and values of an object to the user in a tactile/haptic manner. This purpose is already served by the object label and object value. However, there is a need to be able to access information about the particulars of representation attributes when these attributes are subject to modification by the user. In order to be available to assistive technologies, there is a need to provide textual information on representation attributes.

4.7 Translations

All information attributes may be translated to provide cultural and linguistic accessibility to tactile/haptic objects they relate to. Where explicitly developed, these translations can be stored with a tactile/haptic object as optional additions to the set of information attributes. This should not preclude the ability to create automatic translations where standardized translations have not been explicitly developed and stored.

5. REPRESENTATION ATTRIBUTES

Representation attributes identify the various properties of a tactile/haptic object that the user is intended to physically perceive, including (but not limited to): the identity/name of the object, the state of the object, and/or the data value of the object.

Representation attributes involve both the tactile/haptic coding of objects and additional attributes containing requirements for perceptual differences between various instances of this coding. Tactile/haptic coding can subdivided into: spatial attributes, physical attributes, and temporal attributes, each of which can be further subdivided.

This framework recognizes that it is possible to develop alternate representations (e.g. icons) for tactile/haptic objects that can be used in non-physical media. Such representations could be stored with an object as optional additions to the set of representation attributes. However, the current focus is only on the tactile/haptic representation of objects.

5.1 Spatial Attributes

All tactile/haptic objects involve the spatial attributes of: shape, location, and size. Each of these attributes also exists for visual/graphic forms of interaction. Encodings used for these attributes should be consistent across all media where they apply.

Shape is the most commonly used representational attribute. Simple shapes (e.g. circles, rectangles, etc.) are often used to distinguish a particular type of object from other types of objects (e.g. to distinguish control "buttons" from data entry "boxes"). Abstract and/or complex shapes (e.g. Braille characters) that are recognizable by their intended users may used for specific objects (e.g. particular characters in a specific language).

Location and size may be specified in absolute and relative terms. Their absolute specification can either be used to permanently anchor objects within space or as default values that the user and/or system can restore. Relative specification can be used to maintain relative position and size of an object in relation to other objects (or groups of objects) when part or all of an interface is scaled in size.

Location within a group of objects can be based on various meanings. ISO 9241-14 [6] provides recommendations on ordering menus and ordering items in a menu. ISO 14915-2 [7] provides recommendations on the use of various semantics for structuring content. Similar semantics may also be used to assign a semantic meaning to different sizes of objects.

ISO 1503 [8] provides guidance on the design and use of spatial orientation of objects relative to the user.

5.2 Physical Attributes

Whereas, spatial attributes can be conveyed just as easily via graphical media, physical attributes make use of the unique aspects of touch in tactile/haptic interactions. Physical attributes that may be used for coding include: texture, pressure/force, vibration, and temperature. Each of these physical attributes may or may not be present in tactile/haptic objects. Where they are used for coding, their absence may convey information in the same way that their presence does.

While each of these attributes is often used to provide realism, they may also be used to encode other types of information. Because of their unique applicability to tactile/haptic interactions, there has yet to be any standardization of how they are used to encode information.

It is expected that GOTHI-05 will provide further guidance on the organization and use of physical attributes.

5.3 Temporal Attributes

There are many temporal aspects that may be involved in a tactile/haptic interface. Temporal attributes used for coding include: duration and motion.

Duration is most obvious in real time interactions, where the duration of a tactile/haptic object should be directly related to its relevance to the real time scenario in which it is used. Duration is also important for the use and reuse of tactile/haptic objects, such as the presentation of a sequence of Braille characters by a single object. In both cases there is a need for the duration to be of sufficient length for the user to perceive and act upon the object. Likewise, there is often a need for an inactive spacing between co-located objects or values of objects to ensure that the user recognizes the differences between them.

Motion involves changes in location and/or other spatial and/or physical attributes over time. It can be realistic motion or motion that is intended to represent/code a particular piece of information (such as to draw the user's attention to some area of the interface).

ISO 14915-2 [7] provides general guidance on the use of temporal issues in the design of controls and especially links. ISO 9241-171 [9] provides guidance on the accessibility of temporal objects.

5.4 Perceptual Differences

Spatial, physical, and temporal encodings may be less clearly distinguishable from one another than letters and numbers appear to be when they are presented visually in a clear typeface. There is a need to ensure that any spatial, physical, and/or temporal encoding is perceivable on its own and from similar encodings that represent different values of objects. There is a further need to use this information to warn / guard users against modifying the values of these attributes in a manner that would make resulting objects or object values indistinguishable.

Different attributes have different needs in terns of what a perceptual difference is. In some cases, such as shape differences, these differences need to be determined outside the system and implemented as a list of distinctive values (shapes). In other cases, differences can be specified numerically in terms of a fixed interval between values, or in terms of one value being some percentage grater than the preceding value, or in some combination of these two concepts.

Perceptual differences in one attribute may also be influenced by the values of other attributes used in combination with that attribute. Additionally some users may have disabilities which will make selected spatial, physical, and/or temporal encodings difficult or impossible for them to perceive.

There is a need for standardized guidance in the area of utilizing perceptual differences in determining appropriate spatial, physical, and tactile encodings.

5.5 Combinations

Combinations of spatial, physical, and temporal attributes can be used: to encode different types of information, to redundantly encode the same information, or in combination together to determine the unique encoding of a single piece of information.

It is important that different representational attributes be used consistently and unambiguously throughout an application. This includes their use within combinations.

Because of the vastness of possible combinations, it is not anticipated that detailed guidance will be forthcoming to guide developers in the specific use of different combinations of representational attributes. However, some specific combinations may become de facto standards over time and thus become candidates for specific standardization.

6. OPERATIONS

This model separates object selection from various forms of manipulation (including: activating functions, inputting values, obtaining information, and removing/restoring the object) to provide the user with an appropriate level of controllability and thus to increase accessibility.

6.1 Object Selection

Object selection is considered a separate operation in this model in recognition of its common prerequisite to other operations. In practice, object selection takes place when a user moves some body part (or prosthesis) to a position where interaction with a specific object is possible.

Where a user makes use of vision to select tactile/haptic objects this is a trivial operation that does not require computer support. However, in some circumstances the user needs to be able to tactilely move across a number of objects to the intended object, without inadvertently activating or otherwise manipulating the objects moved across. Achieving this requires a separate computer operation for selection, so that only intentional manipulations are performed.

6.2 Object Manipulation

Tactile/haptic object manipulations include: obtaining (outputting) information, modifying (inputting) attributes, activating processing functions, and removing the object from / restoring the object to the interface. This framework recognizes that there may be various versions of some of these manipulation operations.

6.2.1 Obtain Information

Operations for obtaining information about an object allow a user to find out about the object without activating it. Since there are various types of information about a tactile/haptic object that could be obtained, obtaining information involves determining the desired information attribute(s) and presenting it/them in the desired object information language.

There are a various possible implementations that could be used for determining the desired information, including: using a pre-selected default, having the user select from a list, or using separate operations to obtain each type of information. If pre-selected defaults are used, they need to be user modifiable (as discussed in the previous operation).

The presentation of information about a tactile/haptic object (in response to an obtain information operation) should not get in the way of the user activating the object. Since information attributes are stored in text format, they can be rendered in various modalities. The modality used for presenting information attributes may be based on a user modifiable default.

The method used for obtaining information about tactile/haptic objects and the modality for presenting this information should be consistent for all tactile/haptic objects within an application.

6.2.2 Modify Attributes

Modifying operations can be used to modify the value of a tactile/object object or to modify other attributes of the object. Depending on the needs of the application and the particulars of the implementation, these other attributes may include: representation attributes, default values for other operations, and the object information language.

The most common modifying operation is to modify the value of the tactile/haptic object. A specific "modify value" operation should be provided to easily modify the value of the object currently selected tactile/haptic object.

Since many other associated attribute values might also be modifiable, a separate "modify attribute" operation (or set of operations) should be used to allow the user to select which attribute is to be modified.

The methods used for modifying values and for modifying attributes should be consistent for all tactile/haptic objects within an application.

6.2.3 Function Activation

Many tactile/haptic objects are used as controls that allow the user to perform particular functions. These controls require an unambiguous method of activating them that easily facilitates quick activation while it minimizes the possibility of accidental activation. Because activation is often not the only possible manipulation operation, this method may need to be separate from but work efficiently with object selection.

The demands of real-time applications (such as virtual reality) may require some controls to combine selection and activation into a single user action. In these cases, other forms of object manipulation need to be initiated externally to the tactile/haptic object that is to be manipulated. Such instances are not precluded by the model presented in this paper, since it focuses on different types of operations involving tactile/haptic objects without prescribing how they are implemented.

6.2.4 Remove / Restore Object

Users may be provided the ability to remove or restore individual tactile/haptic objects within an interface. While removing can be implemented as an operation of the particular object, restoring has to be implemented at some level outside the object.

Other operations on a tactile/haptic object, including changing the position and size of an object may be meaningful (as discussed in spatial attributes) and thus should be handled as a form of modifying attributes.

7. GROUPINGS OF OBJECTS

Tactile/haptic objects may be organized in groups and thus be subject to various group level operations. In addition to identifying the group that a tactile/haptic object belongs to, there may be a number of attributes that describe the relationship (in terms of size, position, spacing, and interaction) with other members of the group. Reconfiguring the interface and/or activating a function may affect the group as well as an individual tactile/haptic object within the group, and thus these two operations are illustrated on the border between the individual object and the group of objects.

While this model recognizes the potential for groupings of tactile/haptic objects, it does not provide a detailed model of all of the attributes or operations involved in these groupings.

8. USES OF THIS MODEL

The reference model discussed in this paper can be used both to define unique tactile/haptic objects and to define tactile/haptic implementations of other objects (such as icons) which have been defined for other types of media. This model can be used to help improve the quality of tactile/haptic user interfaces, both indirectly, via standardization efforts, and directly, via implementation activities.

This model is intended to provide a comprehensive format that includes the major attributes and operations that should be defined within standardization efforts relating to tactile/haptic objects. It is compatible with and provides a unique tactile/haptic elaboration to ISO/IEC 11580. It is expected that standardized definitions of tactile/haptic objects based on this model will be placed in the ISO/IEC user interface object registry that will be developed to implement ISO/IEC 11580 compliant user interface object standards.

This model can also be used in the design and construction of instances of these objects. In addition to leading to the development of standardized tactile/haptic objects that they can directly implement, it provides developers with a framework to develop additional tactile/haptic objects that can be implemented (and documented) in a similar manner.

9. REFERENCES

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