

An Ontological View of Human Interface

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Abstract

Today's our life is surrounded by and connected to lots of tools, devices, utensils and computer program applications. Our finger, eye and brain are connected to these things via human interface. From now on, we will use HI as an abbreviated form of human interface. Well-designed HI is the very key factor of practical usability and easy operation of various devices or applications.

In this paper we claim that HI can be viewed through an ontology of machine operation. This ontology is a kind of structured knowledge and gist of corresponding machine or device. The property and quality of HI is straightly reflected in ontology.

When discussing HI, of course the physical aspects of interface, such as forms and shapes of handle, button, lever, pedal, dial, knob, switch, and so on are important; however we claim that these physical matters are also investigated through and/or as device ontology.

We will show some typical example of device ontology laying the foundations of well-designed HI.

Keywords — *human interface, device ontology, lexical structure, meta-physics, machine operation*

1. Introduction

Human interface(=HI) is a kind of conceptive communication system which located between a human and a machine or device, which can be observed clearly through a linguistic ontology. An easy-to-use HI can be viewed as a well-formed communication which achieves goals easily without running into a deadlock. By viewing HI as a communicative process, one can not only account for the way that humans interact with machines to satisfy their goals, but also model the fundamental knowledge to be shared by both humans and machines. Some related arguments are found in [Appelt(1985; 1987)].

The vital issue for designing an excellent HI system is formalizing and grasping the requisite knowledge for man-machine communication so as to enable encoding and evaluating it in concerned machine or device. A similar discussion is found in [Hobbs(1987)]. Encoding is for installing this knowledge in HI systems, and evaluating is for improving the interaction mechanism of HI systems.

In this paper we have a strong interest on the general knowledge structure that exists universally

in various kinds of HI systems. We claim that this universality can be extracted from almost all kinds of HI systems through ontological view. Because ontology is a very basic coordinate system for us human to recognize and discriminate things from others.

Originally ontology is a philosophical concept of old German to investigate the essential nature of existence of all the things in this world. In the midst of highly computerized modern world, Tom Gruber used and expanded the concept of ontology to construct a universal knowledge describing system [Gruber, T.R.(1993)]. Following his idea we can view an ontology as a kind of meta-program specification language to describe new knowledge. Remark that: from our standpoint “knowledge” means “new machine or device manipulation knowledge”. In his ontology, fundamental knowledge specification categories include: entity (individual item, object, class, set), property, relation, condition, constraint, rule (if-then formulae), event.

In order to grasp the basic form of device ontology, we have examined several HI systems including a simple digital watch, an information retrieval system, a word processing system and a machine translation system. Through the examination we will try to elucidate:

- 1) The easy-to-use manipulation of concerned device is highly influenced [or rather determined] by the structure of Ontology of HI.
- 2) The vital function of Ontology is in its referential structure. Each lexical item [or keyword] in Ontology is related to others using this structure so as to form concepts. No items are isolated.
- 3) The referential structure can represent both commands from humans and actions by machines. Roughly speaking, this structure represents a communication structure of corresponding HI systems.

We would like to claim that our Ontological formulation can make a step towards a unified theory of human interface. As the rationale for our claim, we show that several examples of the usability and human-friendliness of HI systems, which can be characterized in a clear form in terms of our Ontology formulation.

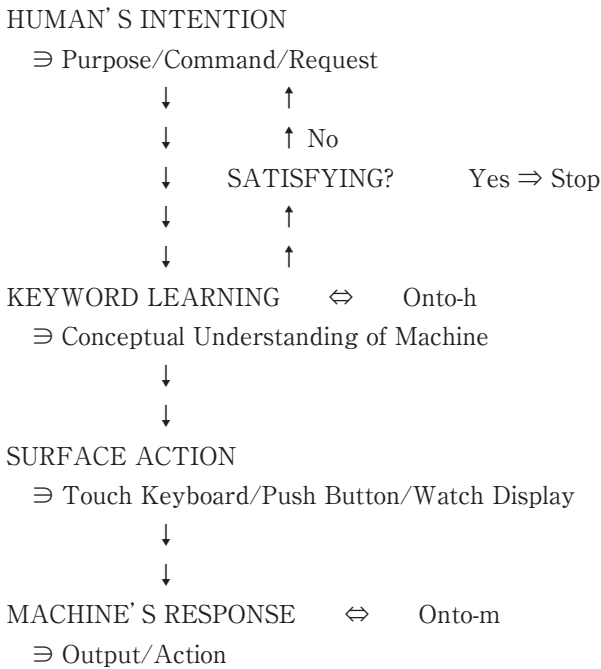
In the following sections, we firstly sketch the communication structure of HI so as to locate the Ontology properly in HI. Secondly, various examples of Ontology are given; among others the simple and illustrative example of Ontology taken from the button-pushing manipulation of the ubiquitous digital watch. Thirdly, we discuss the referential structure of Ontology as the realization of various conceptive functions. Ordinary handy dictionaries are also used to illustrate the referential structure. Fourthly, we discuss the problem of evaluating the quality and feasibility of HI in view of the well-formed Ontology. We claim that Ontology gives us very clear view of HI configurations. Finally, in

conclusion, we summarize the results together with the further problems.

2. Communication Structure of Human Interface

Human interface often takes a form of communication in which human and machine interact each other. The mediums of the interaction are, physically, keyboard touching, dialing, button pushing, lever pulling, display monitoring, and sound or signal alarming. Here we must note that these mediums only represent simple commands or keywords in different ways depending on the machine architectures. Each keyword is a kind of element which represents the human's commands to the machine or the machine's responses to the human.

Thus these keywords form a vocabulary of HI, or more precisely, compose an ontology. In other words, the basic knowledge structure of HI is naturally represented as an ontology which we can call device ontology.



where,

Onto-h = Ontology in Human's Mind

Onto-m = Ontology in Machine Code

Onto-h ≅ Onto-m is the necessary condition for a good/feasible HI.

Fig.1 A Communication Loop in HI with Frequent Access to Ontology

It may be difficult to show a rigid evidence for the existence of our proposed Ontology, but if we admit the existence of the Ontology, it becomes easier to understand the function and mission of concerned machines or devices. We would only like to emphasize that this Ontology is the most natural form for human's systematic recollection and understanding of concerned machine; and at the same time, is the most feasible way for machine to respond to human's request(=command) [Fig.1].

The rest of this paper will be devoted to investigate the various aspects of Ontology in HI through examples.

3. Various Device Ontology

3.1 Simple Example: Button Pushing Operation of Digital Watch

In order to illustrate device ontology, we will examine a simple machine operation. Let us assume we have a digital watch [Fig.2] whose operation manual was accidentally lost. We remark that the digital watch example is originally treated in [Nitta 1988b and 1991]. But so far we cannot find a better example than this for illustrating the importance of device ontology. So here we would like to use the same digital watch example.

Nowadays popular digital watches have lots of functions and displays such as dual time (i.e. a foreign country's time), temperature and moisture, altitude, weather forecast, barometer, point of compass, and so on), but simple and classical watches typically have an appearance as in Fig. 2.

(Time-display button A button B)

Fig.2 A Typical Digital Watch

Let our (i.e. human's) intention be to set the watch to the correct time and to set the alarm.

At first our conceptual understanding of the operation of this strange watch might be quite incomplete. We only know that pushing button A or B is the effective operation needed to carry out our intention. By trial and error we must find the appropriate A-B combination of button pushing. By pushing button A only, we may find something like the diagram below:

$$d(t) \xrightarrow{A} d(al-t-n/f) \xrightarrow{A} d(dt) \xrightarrow{A} d(se) \xrightarrow{A} d(t)$$

where,

$A \Rightarrow$: transition by pushing button A,

$d(\#)$: displaying #,
 t : time,
 al : alarm,
 n/f : on/off,
 dt : date,
 and,
 se : second.

Next by pushing button B only, we may get:

$$d(t) \xrightarrow{B} b(d(al-t-n/f)) \xrightarrow{B} b(d(al-h)) \xrightarrow{B} b(d(al-mn)) \xrightarrow{B} b(d(mo)) \xrightarrow{B} b(d(dy)) \xrightarrow{B} b(d(E)) \xrightarrow{B} (d(mn)) \xrightarrow{B} d(t),$$

where,

h : hour,
 mn : minute,
 mo : month,
 dy : day,
 and,
 $b(d(\#))$: blinking the display of #.

After pushing button-A [one or several times], we may try to push button-B [one or several times], and then get:

$$\begin{aligned}
 d(b(al-t-n/f)) &\xrightarrow{B} \langle \text{no effect/change} \rangle, \\
 d(dt) &\xrightarrow{B} \langle \text{no effect/change} \rangle, \\
 d(se) &\xrightarrow{B} \langle \text{set 0-second} \rangle = d(se).
 \end{aligned}$$

Similarly just changing A and B, we get:

$$\begin{aligned}
 0 = b(d(al-t-on)) &\xrightarrow{A} \langle \text{alarm-off} \rangle = b(d(al-t-off)) \xrightarrow{A} \langle \text{alarm-on} \rangle = 0, \\
 b(d(x)) &\xrightarrow{A} \langle \text{increase } x \text{ by } 1 \rangle = b(d(x)),
 \end{aligned}$$

where,

$$x = al-h \mid al-mn \mid mo \mid dy \mid h \mid mn,$$

and the increase in x follows the relevant modulus (i.e. cyclic increase):

$x = 0 \rightarrow 1 \rightarrow 2 \dots \rightarrow 23 \rightarrow 0$ if $x \neg = \text{al-h} \mid \text{h}$,
 $x = 0 \rightarrow 1 \rightarrow 2 \dots \rightarrow 59 \rightarrow 0$ if $x \neg = \text{al-mn} \mid \text{mn}$,
 $x = 1 \rightarrow 2 \rightarrow 3 \dots \rightarrow 12 \rightarrow 1$ if $x \neg = \text{mo}$,
 and,
 $x = 1 \rightarrow 2 \rightarrow 3 \dots \rightarrow 31 \rightarrow 1$ if $x \neg = \text{dy}$.

The above is the resultant ontological knowledge of the strange digital watch operation. But the diagram shown above is not a proper representation for a human's understanding. The transition diagram is more likely to be the design chart for the digital watch. Human's understanding is closely associated with keywords. In this case, the most likely keyword may be 'mode'. Under the category of 'mode', there are some sub-keywords (or value-words) such as, 'alarm-time' 'alarm-time-set', etc., which indicate the mode of watch. One possible ontological representation of the knowledge is given in Fig.3.

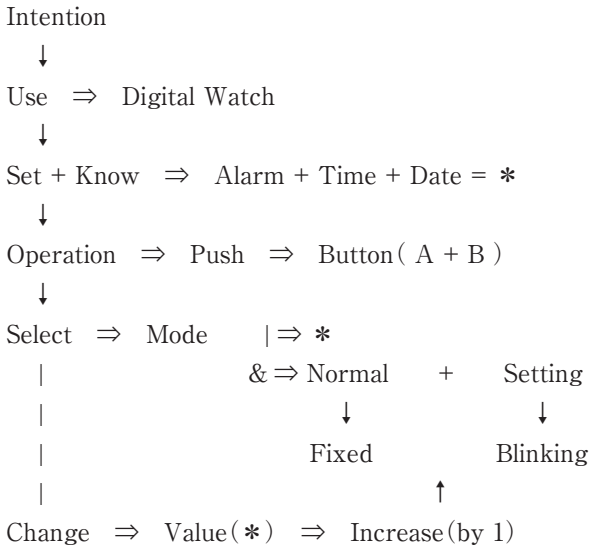


Fig.3 An Intention-Goal Reticulum for Digital Watch Operation with Possible Device Ontology

We should note that even after acquiring some ontological knowledge of the watch's operation, a human user may often make mistakes in watch operations, and have to make trial-and-error to find the correct operation. This trial-and-error is always guided by Ontological Knowledge, as in Fig.3, and not by a transition diagram.

3.2 More Complicated Example: Operation of Word Processor

Currently there are many word processor systems (=WP). Some of them are specially designed hardware devices, and others are software programs installed on general purpose personal

computers. Apart from superficial differences, they share almost the same functional features. The essential usage (i.e. the basic operational concept) is fairly standardized. So, once you get acclimatized to one WP, you can easily master other WPs as well. Omitting the trial-and-error process, we give the outline of a possible Ontological representation for operating a WP in Fig.4 .

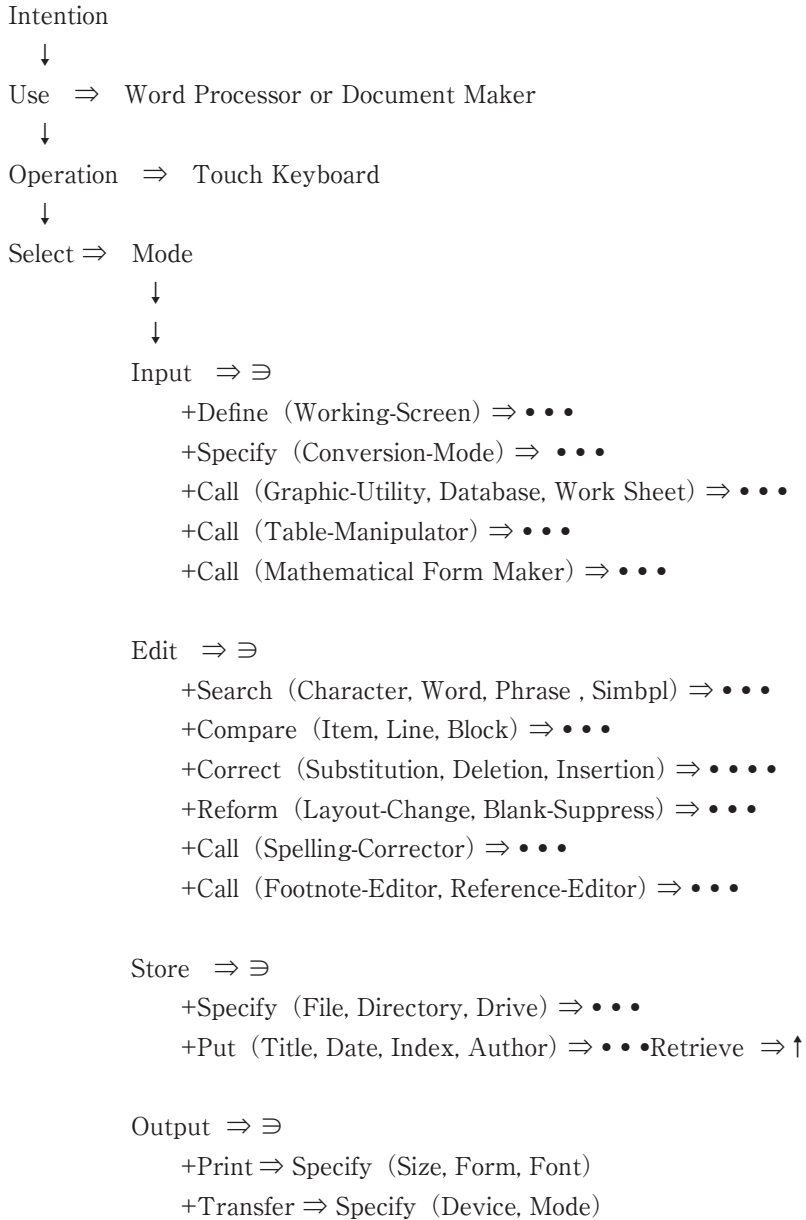


Fig.4 A Fragment of Device Ontology for Using Word Processor or Document Maker Systems

3.3 Linguistic Example: Information Retrieval and Document Searcher

The most classical example for linguistic HI may be information retrieval(=IR) (See [Nitta et al.(1980)]). For IR, the most vital keywords are Store, Retrieve and Index. ‘Retrieve’ means finding an appropriate document from information storage upon a user’s request. Here the Ontology which supports the interface between human user and IR system is usually called a ‘thesaurus’. The thesaurus controls the keywords used both in user requests and document indexes, so that they are standardized and disambiguated.

Let us see a typical example. A combination of keywords:

*Excessive-load * Electric Drill * Burn-off * Motor Coil * Breakdown* is understood as:

‘Putting an excessive load to the electric drill has caused a burn-off of motor coil and breakdown by both human users and IR systems [Nitta et al.(1980)]. The reason for this desirable result is that both of them share a domain specific Ontology like that shown in Fig.5.

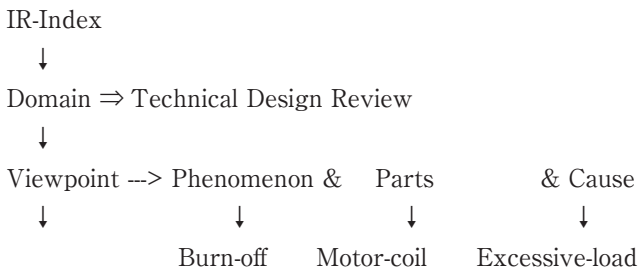


Fig.5 A Domain Specific Ontology Shared by Both Human and IR System

Note that the above is a kind of out-of-date-fashion of information retrieval. Current user can make an information retrieval very easily just by typing the query in natural language sentences in Google or Yahoo or any other document searcher, and get the related document lists. Usually the amount of responding documents is very huge, thus user have to filter them to reach exact documents they expected.

Also note that beneath the fancy automation, natural language sentence query-retrieval, the basic mechanism of information retrieval is almost unchanged as classical mechanism, i.e., keyword-by-keyword matching and retrieving the matched documents via inverted index files. Thus user had better be conscious about keywords (i.e. important words) to specify his/her interests.

3.4 Most Sophisticated Linguistic Example: Machine Translation

The most sophisticated but typical example of linguistic HI may involve proficiency in utilizing machine translation(=MT) systems (See [Nitta et al.(1982; 1984)] for a detailed description.). Here we will not discuss internal operations. We are only interested in the input and output. As is well-

known, the output of MT systems is usually word-by-word translations in an awkward style. Thus user should carefully correct the output translation. Giving hasty credit to the translation output may cause a serious trouble.

4. Referential Relation: Fundamental Function of Ontology

In the preceding sections we have not mentioned the meta-structure of Ontology; rather we just have intuitively used the symbols such as:

‘imply (\Rightarrow)’, ‘or(+)’, ‘and(&)’ and ‘not(\sim)’ for describing the reticulum-structure of Ontology. These symbols have the usual meaning as in mathematical logic. For example, ‘A+B+C’ denotes that each of the three items A, B and C holds alternately; while ‘A&B&C’ denotes that all the three items A, B and C hold simultaneously.

We claim that the most important notion in Ontology is ‘referential structure’ [Nitta(1988a)], which is composed of ‘referential relations’,

i.e.

$A \Rightarrow B$ or $A \Rightarrow f(\dots B \dots)$,

where, ‘f()’ stands for the logical structure described by the above mentioned symbols. In this paper we omit the computationally rigid definition of ‘referential relation’. Instead, we give only an informal explanation together with an illustrative example taken from an ordinary handy dictionary.

The notation ‘ $A \Rightarrow B$ ’ can be read as:

A refers to B,

and the notation ‘ $A \Rightarrow f(\dots B \dots)$ ’ can be read as:

A refers to f($\dots B \dots$).

B may also refer to C, or $g(C, D)$, thus, eventually the collection of referential relations can form the kind of reticulum that we showed in the previous section. This reticulum may often be regarded as a hierarchy or network in ontology.

One noteworthy thing is that the referential relation(s) may form a closed link, that is, a self-reference or recursive reference such as:

$A \Rightarrow f(\dots A \dots)$

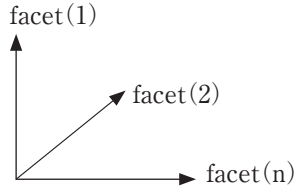
or,

{ $A \Rightarrow B$, $B \Rightarrow (\dots C \dots)$, $C \Rightarrow (\dots A \dots)$ }

In the example above, the lexeme ‘A’ can refer to itself directly or indirectly. In fact, this

phenomenon is often observed in an ordinary dictionary as we will see later.

One more noteworthy structure of Ontology is its 'facet structure' [cf. Nitta et al. (1980)]. The role of a 'facet' is to introduce a kind of semantic orthogonality into the ontology reticulum. Using a geographical image, the notion of a facet can be regarded as one-dimensional independent subspace in an n-dimensional ontological vector space [Fig.7].



$$\text{Ontology} = \text{facet}(1) \times \text{facet}(2) \times \cdots \times \text{facet}(n)$$

Fig.7 The Facet Structure of Ontology

In the previous examples, the following can be regarded as a kind of facet structures:

Use(Digital-Watch) = Set(*) x Know(*),
 Operation = Select(Mode) x Change(Value(*)),
 where,
 *= Alarm + Time + Date,

Select(Mode) = Input x Edit x Store x Retrieve x Output,
 Viewpoint = Phenomenon x Parts x Cause x

A facet is something like a coordinate axis in the conceptual space in a human's mind, and is often called a 'mode', 'viewpoint' or 'stage'.

Finally let us consider some common examples of referential structures inhabiting an ordinary dictionary [See Suganuma and Harris(1982)]:

liquid \Rightarrow substance that is neither a solid nor gas and flows freely like water.
 substance \Rightarrow what a thing is made of; material; matter.
 material \Rightarrow that of which anything is made.
 matter \Rightarrow what things are made of.
 thing \Rightarrow any object or matter.
 solid \Rightarrow matter that is not a liquid nor a gas.

gas \Rightarrow any air like substance.
 flow \Rightarrow move smoothly.
 freely \Rightarrow in a free manner.
 free \Rightarrow not fixed.

Here, we would like to assume that the human's understanding of the word's meaning, to some extent, can be formalized as a unification process on the Ontology (i.e. the dictionary). In order to facilitate the unification, let us rewrite the above descriptions in the notation of predicate logic. For the notational simplicity, we omit the \forall -notation, i.e., instead of ' $\forall x P(x)$ ' we simply write ' $P(x)$ '. Using this we obtain:

$$\text{liquid}(x) \Rightarrow \exists \text{ be-made-of}(y,x) \wedge \text{like}[\text{ff}(x), \text{ff}(w_i)] ,$$

where,

$$\text{ff}(\cdot) \Rightarrow \sim \text{fixed} \ \{ \text{smoothly} \ [\text{move}(\cdot)] \} ,$$

w_i = a definite w such that $\text{water}(w)$ is true.

Here ' $\text{be-made-of}(\cdot)$ ' and ' $\text{like}(\cdot)$ ' are basic Ontology keywords in ordinary human intelligence. The referential structures for ' $\text{fixed}(\cdot)$ ', ' $\text{smoothly}(\cdot)$ ' and ' $\text{move}(\cdot)$ ' are omitted.

We have shown that feasible HI and smooth communication is supported by the Ontology, where the referential structure takes an important role. As shown in the previous section, 'hierarchical structure' is a special type of referential structure.

5. Upper Ontology for Human Interface

The upper ontology is defined to be the sub-ontology that located at the top position among all other ontologies and thus can command the entire domain of involved ontologies. The upper ontology is sometimes called otherwise such as upper-level ontology, top-level ontology, general ontology, general purpose ontology [Takeda, H.(2004)] [Bateman, J., Henschel, R., and Rinaldi, F.(1995)] [Jurisica, I., Mylopoulos, J. and Yu. E.(1999)].

We claim that upper ontology for human interface should reflect directly the intuitive understanding, natural association, commonsense of ordinary people (i.e. not "of device designer and makers") . If concerning device ontology could have a natural linkage to the well-designed upper ontology, this concerning device would have a good (i.e. easy-to-use and easy-to-understand) human interface.

Let us take requisites for good easy-to-use human interface system from the man-machine

conversation. [Fitzgerald, W. and Firby, R.J.(2001)] said “Humans have the ability to act and react to the environment even as they carry out tasks.” and further he describes the plan that human has his mind before acting:

- 1) Plans can be *sketchy*, that is, the tasks to be carried out must be describable at appropriate levels of abstraction.
- 2) Plans can have *multiple ways to succeed*; and, having multiple methods to achieve success, must carry the *contexts under which each method is appropriate*.
- 3) Plans must carry their *success and failure conditions* which are checked while tasks are being carried out (“run-time conditions”). Because the world is complex and dynamic, success and failure must be determined at run-time, not just projected at compile time.
- 4) Plans can provide for *breakdown*, that is what to do when failure occurs.

Also he gives examples of shared requirements between man and machine such as:

- 1) Agents can have multiple goals active simultaneously,
- 2) Agents can be attempting to achieve these goals simultaneously,
- 3) The world in which agents act is often unpredictable and often changing,
- 4) Tasks and goals can be described hierarchically,
- 5) Resources available for achieving goals vary,
- 6) Goals can have differing priorities, which may vary dynamically,
- 7) Agents will sometimes fail to achieve their goals,
- 8) Multiple agents will be attempting to achieve their goals simultaneously, perhaps collaboratively.

The above items give a good guideline for constructing upper ontology for device ontology.

Next let us take a look at “iOS human Interface Guideline [Apple Developer(2012)]”.

As a principle design concept for “platform”, they list up following items.

- 1) Platform is the most important part in iOS application regardless of its size.
- 2) Device should be changeable of its facial direction.
- 3) Application should be sensible to user’s gesture rather than their click.
- 4) User can make a dialogue with device one at the one time; They cannot manage to handle simultaneous plural talks (or tasks).
- 5) Device environment change should be and can be made uniformly in general setting mode.
- 6) Help message and service on the screen should be minimized.
- 7) Many of the applications of iOS use a single window.
- 8) Two kinds of software are to be executed under iOS.
- 9) The staff of iOS should provide users Web-interface.

As the principle of good Human Interface, they list up the following items.

- 1) Conformity of Appliances
- 2) Consistency
- 3) Direct Manipulability
- 4) Feedback
- 5) Metaphor
- 6) Controllability by the User's Will

The above items form at the same time the necessary condition for good upper device ontology.

6. Criteria for Well-formedness of Ontology: Method to Improve Human Interface

In this section we claim that the quality of HI to some considerable extent, can be evaluated through observing the structure of the Ontology.

The criteria for evaluating the well-formedness (i.e. quality) of Ontology are given by:

Onto-h \cong Onto-m \Rightarrow HI is feasible,

Onto-h \neq Onto-m \Rightarrow HI is awkward,

where, Onto-h is Ontology in human's mind, and Onto-m is Ontology of machine designer or maker.

The consistency between 'the user's natural expectation of the functions' and 'the machine designer's original intention' is the key to good or feasible HI. And this consistency can only be seized by observing the homology of both human's and machine's Ontology reticulums. In other words, well-designed upper device ontology gives a well-designed Human Interface.

7. Conclusion

In this paper we have claimed, and tried to demonstrate with some examples, that a feasible human interface is supported by the use of ontology shared by both human users and machines. And as natural consequence of this, we have claimed that the essential aspects of Human Interface can be visualized in an abstract and neutral manner through the Ontology reticulum. Thus the criteria for the feasibility or awkwardness of Human Interface can also be obtained by observing the structure of Ontology.

The most important function of Ontology is formalized as its Referential Structure, which we have emphasized often in this paper together with the ordinary but canonical examples. It is the Referential Structure that forms the basic conceptual structure of Ontology so as to facilitate feasible Human Interface. In other words, owing to this Referential Structure, we humans can have easy access to the knowledge necessary for operating and/or manipulating various machines.

The Ontology formulation may seem to be somewhat biased to the lexical functional (that is ontological) aspects of Human Interface; and indeed, in this paper we have discussed such aspects only.

Needless to say, the emotional and sensuous aspects, such as, finger-touch feeling, manipulative smoothness, visual impression, and readiness, are also inevitable factors in the criteria for good Human Interface. These factors should be evaluated by experimental operations in parallel with ontological and/or lexical-functional evaluation.

But further we claim that even these emotional and sensuous items can also be formalized as Device Ontology. Some relating and supporting researches are found in [Ortony,A., et al.(1987)].

Extending our Ontology formulation to accommodate sensuous factors is a task for further work. We are also planning to construct a program that can generate a conversational Human Interface System for aged people by interpreting the Upper Ontology for aged People Society.

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