Conditions of Applications, Situations and Functions Applicable to Gesture Interface

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Abstract. Although there were many studies related to developing new gesture-based devices and gesture interfaces, it was little known which applications, situations and functions are applicable to gesture interface. This study developed a hierarchy of conditions of applications (devices), situations and functions which are applicable to gesture interface. This study searched about 120 papers relevant to designing and applying gesture interfaces and vocabulary to find the gesture applicable conditions of applications, situations and functions. The conditions which were extracted from 16 closely-related papers were rearranged, and a hierarchy of them was developed to evaluate the applicability of applications, situations and functions to gesture interface. This study summarized 10, 10 and 6 conditions of applications, situations and functions, respectively. In addition, the gesture applicable condition hierarchy of applications, situation and functions were developed based on the semantic similarity, ordering and serial or parallel relationship among them. This study collected gesture applicable conditions of application, situation and functions, and a hierarchy of them was developed to evaluate the applicability of the gesture interface.

Keywords: Gesture interface, Applicability, Gesture application, Situation, Functions.

1 Introduction

As different devices for advanced technologies such as smart-home systems, robots, and large screen displays appear in the market, the demands for more applicable interfaces have increased for such devices. Moreover, recent technologies have allowed the consumers to have more intuitive interactions with the devices, and the gesture interface is one of those recent technologies that have been introduced [21].

There has been an active movement in the recent literature on how to incorporate the gestures with various interface technologies. The earlier research studies have

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focused on developing new devices and applications that incorporate such gesture interfaces [2] while recent studies are more focusing on the architecture of gesture vocabulary and the evaluation of gesture applicability conditions [9].

However, the current literature still lacks the research on understanding which applications, situations and functions (or commands) to incorporate such gesture interfaces. The current research in the field of ergonomics has conducted studies on developing more intuitive gestures and evaluating the applicability of such gestures. However, in order to increase the utility of the gesture interfaces, more studies on determining which applications, situations and functions to apply the gesture interfaces need to be first investigated before developing and evaluating the gestures themselves.

This study has gathered and systemized the conditions of the device, situation and function to appropriately apply the gesture. From studying the existing studies related the gesture interface, we have collected the information on the conditions of the device, situation and function for the gesture applicability and have developed a system for them. The conditions derived from our study may be utilized as categories to evaluate the applicability of the gesture for a device, situation and function prior to designing the gestures. However, detailed outline and guidelines are necessary in order to utilize the conditions in practice.

2 Method

In order to develop a guideline for evaluating the gesture applicability, this study has collected the information from the existing studies on the design, evaluation and application of the gesture interface and has derived the categories for the conditions of the device, situation and function to apply the gesture interface. About 120 studies have been considered, but only about 16 of them were closely related to the concern of our study. Wachs et al. [21], which concerns the necessary conditions of the generalization of the interface, has also mentioned the lack of such studies in the literature

This study has utilized the categories derived from the existing studies to organize and systemize the conditions of the device, situation and function to apply the gesture interface. The collected conditions were categorized according to the similar meanings and the level of the applicability.

3 Application Conditions

3.1 Hierarchy of Application (Device) Conditions

The conditions of a device for applying the gesture interface are categorized into 10 different criteria: price and cost, communication, behavioral pattern, entertainment, security, spatial manipulation, remote control, urgency, sterility, and support for elderly and disabled.

Figure 1 shows the hierarchy of device conditions. Except the price and cost, the rest of the conditions are categorized into three characteristics of a gesture: naturalness, expressiveness, and contact-free. Naturalness concerns communication and behavioral pattern, while expressiveness concerns entertainment, security, and spatial manipulation. Contact-free concerns remote control, urgency, sterility, and support for elderly and disabled. The further discussion of the device conditions are found in Ch. 3.2 through Ch. 3.5, while Ch. 3.6 explains the usage of the device conditions for evaluating the applicability of the gesture interface.

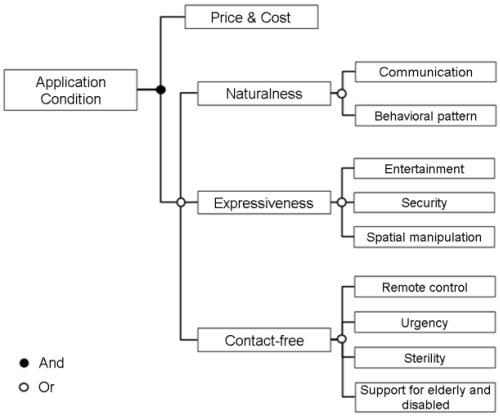

Fig. 1. Hierarchy of application (device) conditions applicable to gesture interface

3.2 Price and Cost

The production cost and the price of the devices should fall within the reasonable range in regard to the gestures that are applied. In other words, the production cost with the gestures applied should not be higher than those without, and the efficiency of the final devices should be worth more than the cost of the production [9].

3.3 Naturalness (Natural Interaction)

The devices require natural communication with the gestures; gestures refer to the physical movement acted during communication with oneself or others [5]. Gestures are naturally accompanied by verbal communication during interactions among men [1]. Therefore, the devices, to which the gestures are applied, should also find such gestures useful for the communication with the users. For example, robots are often aided by the gestures of the human users to successfully accomplish the tasks. Vacuum cleaning robots such as Roomba and robot pets such as AIBO are further developed with control interfaces for allowing natural gestures of the human users.

Moreover, certain applications detect and recognize different conditions of the users such as drowsiness and excitement through their natural depiction of gestures. The emotions and physiological conditions are often depicted through the users' head

movements and face expressions [11]. For example, drowsiness is often recognized by the user's head movement while surprise or anger could be recognized by the face expression. Such gestures are considered passive and can be utilized to recognize false witness, nervousness, drowsiness, distress, and related conditions and emotions.

3.4 Expressiveness

The devices that are in need of the gesture interface should allow diverse expressions of gestures and have a certain purpose of entertainment. As Mitra and Acharya [11] have defined the gesture as a meaningful and expressive body movement, the gesture itself has a purpose of expression. Gestures that are focused on expressions convey different human emotions [11], while offering different pleasures of expression (e.g., dance and performing arts), and are also used for showing individuality of the performers [8]. Therefore, the devices should be also in desire of expressive gestures.

The most common cases of such devices are video game consoles. Gaming devices like Nintendo Wii and Xbox Kinetic have gained the popularity for their diverse range of expressive gestures. Moreover, the individuality conveyed through the gestures is also utilized in security systems such as door locks and alarm systems [8].

In addition, another meaningful information of the gestures is spatial information, and the devices should also be benefited from such information. Gestures provide spatial information such as location and direction and can be most utilized for controlling an object in space. Particularly, the gestures may be most effective than other interfaces in three-dimensional space [16], and large and high screen context which deals direct manipulation are most benefited from the gesture interface [3].

Devices that may be benefited by the gesture interface are visual architecture applications, 3D virtual reality systems, Smart Design Studio [8], and other related large-screen systems.

3.5 Contact-free

Since the gestures are often made without physical contact of the devices, contact-free is a basic characteristic of the devices for the gesture interface. Although certain applications of touch-screens are utilizing the gestures that are in contact of the device, the demand of contact-free gestures would increase in other ubiquitous environments. The contact-free gestures are beneficial in terms of remote control, urgency, mobility, sterility, and support for elderly and disabled [22].

The examples of the applications that utilize the contact-free characteristic of the gestures are smart TVs linked with smart-home systems, emergency systems, medical devices, and disability aids [22]. TVs often require remote control, and there have been studies on developing such applications centralized by smart-home systems [9, 14]. Moreover, emergency system has been developed for higher effectiveness through the gestures that do not require physical contact of the controllers for various emergency situations [17]. Medical devices require cautious usage due to the possible infections, and certain devices such as FACE MOUSe [13] have been introduced to utilize the face expressions into the gesture interface. Lastly, wheelchairs have been

developed to aid the disabled people to manipulate more easily without much of the muscle strengths [7].

3.6 Usage of Conditions in Evaluating Applications

The devices must satisfy the condition of the production cost and product price, as well as at least one of the rests of the conditions. Therefore, as Figure 1 shows, the evaluation logic has been established with the AND condition between the production cost and the rest of the conditions (naturalness, expressiveness and contact-free), which have the relationship of the OR condition. Likewise, the lowest level of the conditions of naturalness, expressiveness and contact-free must also go through the OR condition to have at least one of them satisfied.

4 Situational Conditions

4.1 Hierarchy of Situational Conditions

A total of 9 conditions have been collected from the existing studies for the situations to apply the gesture interface: physical availability, attention resource, space, posture, recognition error reduction, noise and interference, social acceptance, visibility, and minimal speech.

These situational conditions have been organized into two large categories of allowance and necessity, as shown in Figure 2. The further explanations are discussed in Ch. 4.2 and 4.3, and the usage of the conditions is discussed in Ch. 4.4.

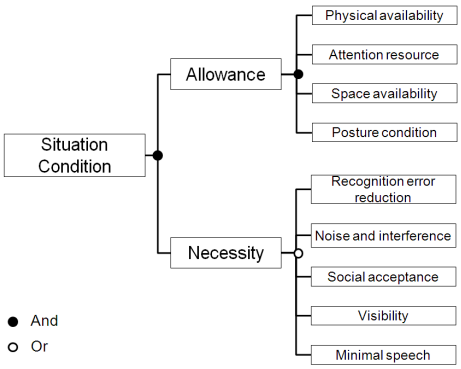

Fig. 2. Hierarchy of situation conditions applicable to gesture interface

4.2 Allowance Condition

The first situational conditions for the gesture interface to be applied are the allowance of the situations. The allowance conditions comprise of physical availability, attention resource, space, and posture. First, physical availability refers to

the availability of the body parts for gestures such as hands and heads; if such body parts are already occupied to manipulate the device, this condition is not met. For example, if the user is carrying a device with both of his hands, then physical availability is quite low for the hands.

Attention resource refers to the availability of the resources for the user to pay attention to his gestures; if the user is preoccupied with tasks to process the spatial information or is going through manual tasks that require the user's immediate responses, this condition is not met [23]. Therefore, attention resource is a necessary condition among others to satisfy the situational conditions.

Moreover, the situation must allow sufficient space for the users to make gestures and postures.

4.3 Necessity Condition

The second situational conditions for the gesture interface are the situations where the interface is necessary. The necessity conditions consist of recognition error reduction, noise and interference, social acceptance, visibility, and minimal speech. Gestures are advantageous when there exists large errors in multimodal interactions while recognizing voice commands; the gestures provide another modality to the system to reduce the recognition error and thus are necessary in such situations [16]. Gestures are also necessary in situations where there exists noise or an obstacle that interferes the voice commands [19]. Moreover, there may be situations when the social acceptance is low for voice commands to be at a high volume [18]. Lastly, situations where visual information is lacking, such as in dark places, and where it requires minimal speech are both in need of the gesture interface [15].

4.4 Usage of Conditions in Evaluating Situations

The situations must satisfy both the allowance conditions and the necessity conditions. Therefore, these two groups of conditions are evaluated under the AND condition as shown in Figure 2. The gesture interface may only be applied when all of the allowance conditions are met; thus, these conditions are evaluated under the AND condition as well. Meanwhile, only one of the necessity conditions satisfy the situation to have the gesture interface applied, and they are evaluated under the OR condition.

5 Functional Conditions

5.1 Hierarchy of Functional Conditions

In the case of functional conditions, there have been a total of 7 conditions collected from the existing studies: simple and basic, repletion in short time, short-cut, immediateness, spatial information, spatial metaphor, and symbolic meaning.

These conditions are grouped into three categories of allowance, necessity and easy expression as shown in Figure 3. The allowance conditions are simple and basic and repletion in short time. The necessity conditions are short-cut and immediateness, and the easy expression conditions are spatial information, spatial metaphor and symbolic meaning. The further explanations of the conditions discussed in Ch. 5.2 through 5.4, and the usage of the conditions in evaluation is discussed in Ch. 5.5.

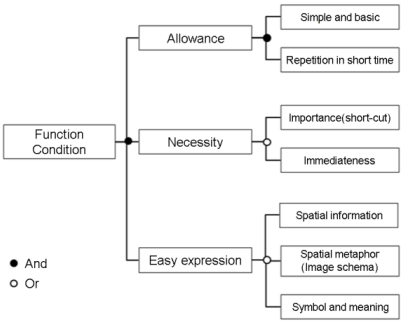

Fig. 3. Hierarchy of function conditions applicable to gesture interface

5.2 Allowance Condition

Allowance condition refers to a function that is simple and basic and is supplied in short time in order to apply the gesture interface. Simple and basic functions refer to single-unit tasks followed by immediate responses and results [8]. For example, tasks such as turning on/off a TV and increasing/decreasing audio volume are basic tasks that do not require further process of functions. Functions that request continuous gestures for more than one process of tasks are often complicated and have trouble recognizing the gestures. The users also find the gestures difficult to make in such cases.

Repletion in short time means lower frequency of the tasks. Gestures are highly involved with the user's muscle movements and thus may be tiresome if repeated for several times within a short period of time [24]. Therefore, repletion in short time is necessary for the gesture interface so that the users do not become fatigued [12]. For example, frequent change of channels may easily tire the users.

5.3 Necessity Condition

The functions to which the gesture interface is applied must be important and must require immediate reactions. Such functions should be used more frequently than others and should benefit from having short-cut features [20]. For example, remote-controlling TVs occurs frequently and is an important task, and thus a gesture interface is necessary.

Moreover, such functions must be in need and urgency of immediate tasks [8]. For example, the mute function is an immediate task of reducing the volume of a TV and would benefit from having a gesture interface.

5.4 Easy Expression

Lastly, the functions should be easy to replace with gestures to benefit from a gesture interface. Such functions deal with spatial information, spatial metaphor and symbolic meanings. The functions that are closely related with spatial information and movement information are easy to incorporate with a gesture interface [16]. For example, selection of a target, change of a location, size manipulation, and direction change are easy to apply the gesture interface.

Functions that could be related to abstract concept of the space are also easy to replace with gestures. For example, studies like Hurtienne et al. [6] have shown that concepts such as good/bad, close/far, center/circumference, and forward/backward are often explained with spatial metaphors and may be easily replaced by gestures.

Moreover, functions with symbolic meanings are easy to apply the gesture interface. For example, functions related to letter editing, and numbers or symbols could be easily replaced by gestures [16, 8].

5.5 Usage of Conditions in Evaluating Functions

The functional conditions must be satisfied to apply the gesture interface in terms of allowance, necessity and easy expression. Therefore, all three groups of conditions are evaluated under the AND condition as shown in Figure 3. Also, the further conditions of allowance must be all satisfied and thus are evaluated under the AND condition. On the other hand, at least one of the necessity conditions and of easy expression conditions should be satisfied and thus are evaluated under the OR condition.

6 Discussion and Conclusions

This study has proposed a development of systematic evaluation of the device (application), situational and functional conditions prior to incorporating a gesture interface. The evaluation of such conditions may benefit to provide easier tools to design the gesture interface, but research studies on developing such evaluation methods are still lacking in the literature. The conditions introduced in this study are collected from the context of the existing studies and thus are reliable resources to propose a systematic approach of evaluating the conditions to apply the gesture interface.

However, the evaluation method of the conditions discussed in this study still suggests further improvement. First, the conditions collected through this study do not comprehend all the possible conditions to evaluate the applicability of the gesture interface; thus, further investigation on collecting data is necessary. Second, further

discussion and validation are necessary to confirm that the collected conditions are the most appropriate to evaluate the applicability of the gesture interface. Moreover, further research is necessary to validate the system proposed in this study to categorize the conditions.

This study introduces the following process to utilize the device, situational and functional conditions for evaluating the applicability of the gesture interface. First, a complete mapping of the conditions must be developed for objective and comprehensive evaluation. The conditions are ambiguous and abstract to be appropriately evaluated. For example, frequency of the functions may be utilized as evaluation methods to measure the weight of functional necessity. Second, further categorization is necessary for objective evaluation of the conditions. For example, in the case of evaluating the necessity of the functions, detailed guidelines must be present in order to quantify the frequency of a function usage.

The further direction of the study focuses on improving the system of evaluating the applicability of the gesture interface. Based on the developed system, further methods of evaluating the device, situation and function will be developed. Moreover, validation of the system will be conducted with practical devices, situations and functions. Further development of the methods to evaluate the conditions themselves will also be considered.

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