DESIGN BY ACTIONS

An Affordance-based Modeling System in Spatial Design

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Abstract. From the viewpoint of interaction design, Gibson's affordance concept is interpreted as an emergent action possibility of the physical human-environment-system, which consists of three key components: the user, the environment, and the possible actions. It could help user to perform the suitable action within an artificial environment. This study aims to develop a formal description of affordance in spatial design. Using the formal description as groundwork, an affordance-based modeling system is then proposed to facilitate its further implementation in design and elucidate the new role of users and designers in spatial design. A simplified sink area design is used as an example to illustrate how this affordance-based modeling system works. For users of different conditions, different spatial arrangements in design will affect the performance and users' behavior as well. This study demonstrates how design by action can be achieved, and then simulates the action sequence of different design solutions to evaluate the system performance.

1. Introduction

The relation between the human and the object has been a major issue for many well-established disciplines, for instance, psychology. Among the various theories related to human-environment interaction, the theory of affordance has received significant attention in design literature (Dourish 2001). An affordance is a resource that the environment "offers" to an organism that possesses the appropriate perceptual and locomotor ability to respond it (Gibson, 1979). This study aims to develop a formal description of affordance in spatial design. Using the formal description as groundwork, an affordance-based modeling system is then proposed to facilitate its further implementation in design.

2. Ecological Approach and Affordance

Contrast to the mainstream cognitive psychology, Gibson (1979) developed an alternative, "ecological," approach that emphasizes the information to guide the actions of animals and people exists naturally in the environment. The term affordance is coined to mean the use-value of environmental objects taken with reference to the users' physical capabilities. Affordance is about the action possibility available in a human-environment system. Its existence is relative to physical conditions of users, and independent of the user's awareness, need and expectation.

Following the framework proposed by a previous study (You, et al. 2001), which suggested affordance as a three-way relationship among user, environment, and action, a system is presented to use "action" to describe a spatial design.

3. The Formalism

An affordance is a relative property between the user and the environment. Thus, the user, the environment, and the action possibility form the basis structure of the formal description of affordance. The basic logical structure of affordance is expressed as the following formula:

$$\textbf{\textit{Action = Affordance (User, Environment)}} \quad (1)$$

The formula means "The '***Affordance***' relation hold between '***Environment***' and '***Use***r' affords '***Action***' to the human-environment-system".

In order to describe and identify the characteristics of the user, a set of different "attributes", such as height, posture…etc., is identified to express the condition of users. Assumed there are a finite number 'n' of "user attributes", a_1, a_2…and a_n. Hence, the universal set of the user attributes under consideration can be expressed as '***A***':

$$A = \{ a_1, a_2, \ldots, a_n \} \quad (2)$$

Hence, a user can be formulated as a subset of 'A'. For instance, a user 'u', whose current condition consists three attributes a_2, a_3, and a_5; then the user 'u' can be described as the following set:

$$u = \{ a_2, a_3, a_5 \} \tag{3}$$

In the similar fashion, the environment can be expressed as a subset of the universe 'F', which includes all of the environment features $f_1, f_2, \ldots, f_m$; then the environment 'e, whose current condition consists two features f_1 and f_4', can be described as the following set:

$$F = \{ f_1, f_2, \ldots, f_m \} \tag{4}$$

$$e = \{ f_1, f_4 \} \tag{5}$$

If the environment 'e' offers action 'X' to the user 'u'. Then the affordance for 'X' can be expressed as following formula:

$$X = Affordance\ (u, e) = Affordance\ (\{ a_2, a_3, a_5 \}, \{ f_1, f_4 \}) \tag{6}$$

Once affordances in a human-environment-system are defined as the formalism proposed, these three-way relationships can be used as rules to simulate or control interactions in the system.

4. An Affordance-Based Modeling System

From the viewpoint of interaction design, the primary function of a spatial design can be seen as the intended outcome of a sequence of correct actions which are driven by users' needs and available affordances. Every action the user takes will either change the condition of the user which can open new action possibilities, or modify the conditions of the environment to approach the goal state. Through interactions, the condition or status of the overall human-environment-system is changed constantly, thus the affordances exist are dynamically changed as well, until the intended status of the system is reached.

The above-mentioned formalism is used as groundwork to present the status of a human-environment-system. A given affordance relationships involved in the design is used as the rules to generate the action possibilities from the condition of the system status.

However, these affordance relations can only handle action possibilities but not their outcomes. A mechanism to update the current status of the system is required; hence, a set of action rules is given to express the changes in the system for each action involved in the design process.

Although we intend to develop an affordance-based modeling system, the user behavior is not triggered by affordances only. It can be also driven by the user's goal. Instead of being a passive participant, the user can initiate certain posture changes to alter his or her properties, and thus affect the affordances of the system to explore new path for achieving the goal. Hence, in this design system an additional set of rules to control the user-initiated action is needed.

5. Example: Affordance-Based Modeling System for Sink Area Design

A simplified sink area design is used as an example to illustrate how this affordance-based modeling system works. The affordance-based modeling system includes the component modules to represent user, environment, and action, and two set of rules to guide the affordance identifying and action simulation.

5.1. THE COMPONENT MODULES

Set-theoretical notation is adopted to represent the three components, user, environment, and action. A universal set for each is given to define the scope of this case.

The universe of user attributes '***Ua***':

Ua = *{stand-up, hunker-down, empty-handed, full-handed}* (7)

The universe of environment features '***Ef***':

Ef = *{high, low, faucet type1, faucet type2, faucet type3, faucet type4, on, off }* (8)

The universe of actions supported by affordance '***Af***', and initiated by user '***Au***':

Af = *{turn, push, place in front of, place under}* (9)

Au =*{stand, hunker, put down, pick up}* (10)

The overall condition of the human-environment-system consists of the condition of the user and the environment. Hence the situation "*an empty-handed adult stands in front of a table height, lever-handled, flowing faucet*" is expressed by its status as following:

({stand-up, empty-handed}, {high, faucet type2, on}) (11)

Figure 1. Four types of faucets used in this study

5.2. THE AFFORDANCE RELATIONS

An exhausted list of affordance relationships for the four actions in '***Af***' is used as the rules to generate the action possibilities. Due to the scope of this paper, only affordances for '*push*' are presented.

{push}= ***Affordance*** *({stand-up}, {high, faucet type2})* (12)

{push}= ***Affordance*** *({hunker-down}, {low, faucet type2})* (13)

As the affordance relation expressed in formula (12), the condition required to support the action possibility '*push*' is, first, the height of the faucet should match users' posture; second, the faucet should be lever-handled as faucet type 2. When the required condition is a subset of current status, the action possibility is identified.

5.3. CAUSE-EFFECT RELATIONS

In order to simulation the human-environment-interaction, the cause-effect relations between an action and its outcome is given to reflect the changes in the system. For every action executed by users, there exists a cause-effect relation to update the status of the system. For instance, the action '*stand*', which is initiated by users, can only change the user condition. In the formulism, the rule based on this cause-effect relation will replace the '*hunker-down*' element with the new element '*stand-up*' in the expression of the user. Another action 'push', which is provided by the affordance relation, can physically change the environment condition, and turn on the faucet; thus the rule for the cause-effect of '*push*' will replace the '*on*' element in the expression of the environment with the new element '*off*' , and vice versa.

5.4. SIMULATION OF HUMAN-ENVIRONMENT-INTERACTION

The following case will demonstrate how *"a full-handed, standing-up use*r" in "*a knee-height sink area with a turned-off, rotary faucet*" can complete the task, "*washing hands*". The goal can be express as "*an empty-handed user and a flowing faucet with the matching height*." The interactions of the user and the sink area design are simulated in an action-sequence manner.

Step 0. Initial state of the human-environment-system:

({stand-up, full-handed}, {low, faucet type1, off}) (14)

Step1. Comparing with the rules of affordance relation, no action possibility is identified. To change the status of current system, the cause-effect relation *'hunker*' is applied to change the user's condition.

({stand-up, full-handed}, {low, faucet type1, off}) $\xrightarrow{hunker}$
({hunker-down, full-handed}, {low, faucet type1, off} (14)

Step 2. Two action possibilities, '*place in front of*' and '*place unde*r', are identified. However these two actions can not turn on the faucet, which is part of the goal. Thus again, the cause-effect relation '*put down*' is applied to change the condition of user.

({hunker-down, full-handed}, {low, faucet type1, off} $\xrightarrow{put\ down}$
({hunker-down, empty-handed}, {low, faucet type1, off} (16)

Step 3. Three action possibilities, '*place in front of*', '*place under*', and '*turn*', are identified. The cause-effect relation '*turn*' is applied to change the condition of environment.

({hunker-down, empty-handed}, {low, faucet type1, off} $\xrightarrow{turn}$
({hunker-down, empty-handed}, {low, faucet type1, on} (17)

The current status satisfies the required condition of the goal. Through the simulation, the interactions required for hands-washing task is achievable, thus the performance for the sink area design can be evaluated.

6. Conclusion

Based on the theory of affordance, the environment is not '*a patchwork of forms*' to users, but the possibilities of actions. Through interacting with the environmental objects, users can open up a sequence of actions to achieve their goals at last. Hence, works of the environmental design can be described as a sequence of interactions. Designers can manipulate properties of environments in the design process to await the emergence of functional affordances for target users. Using affordance as a basis, this paper outlines a design framework of human-environment interaction to elucidate the new role of users and designers in spatial design.

A simplified sink area design is used as an example to illustrate how this affordance-based modeling system works. For users of different conditions, different spatial arrangements in design will affect the performance and users' behavior as well. This study demonstrates how design by action can be achieved, and then simulates the action sequence of different design solutions to evaluate the system performance.

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