# Affordance Feature Reasoning in Some Home Appliances Products

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**Abstract**
Interactions between human and objects are made through specific features of the object, which are adequate to the task context. During interactions, the perceived features vary according to the context. Affordances are the messages that products provide and users perceive in such a way that user actions are naturally induced with the help of such messages. In this research, we define affordance features as structural elements providing affordances. We classify affordance features into functional, ergonomics, and informative aspects. For some home appliances, common affordances and affordance features are identified so that they can be used in designing other products.

**Keywords**:
Affordances, Affordance Features, Task Context, Home Appliances Products

## 1 INTRODUCTION

Affordance is considered as the properties of the product inducing human actions for operation[1][2]. Interactions between human and objects are made through specific features of the object, which are adequate to the given task context. During interactions, perceived features of the object vary according to the context given to human. For example, grasping features of an object are critical in grasping and manipulation features, at control. Features can be implicated as engineering significant aspects of the geometry of a part or assembly and thus plays a very import role in product design, product definition and also reasoning for various applications [3] [4]. That is, feature concept earlier used in design and manufacturing satisfies the structural aspect for product as needed to provide affordances.

Affordance was coined by perceptual psychologist James Gibson. His essential concept of affordance is that relationship exists in a pair of animal and environment and some parts of this relationship are the invariant features of the environment permitting the animal to do things [1]. From the investigation of affordances of everyday things such as door, telephone and so on, it was argued that the form of everyday things provides strong clues to their operation as a result of the mental interpretation of them, where the mental interpretation is based on human's past knowledge and experiences [2].

On affordances for complex actions, Gaver introduced two concepts of affordance such as sequential affordances and nested affordances [5]. Sequential affordance is about situations in which one action on an affordance leads to new affordances over time, while nested affordance is concerned with grouping affordance in space.

In the field of engineering design, the research efforts to develop the design theory and methodology reflecting the concept of affordance have been considerably made. Maier and Fadel proposed the Affordance-Based Design (ABD) methodology [6][7]. In the ABD, affordances are categorized into positive affordances (what the artifact should afford) and negative affordances (what the artifact should not afford) as well as artifact-artifact affordance (between multiple artifacts) and artifact-user affordance (between artifact and user). Maier *et al.* introduced Affordance-Structure-Matrix (ASM) for evaluating what affordances are embedded in each component of a product and thus grading. This matrix can illustrate correlations of affordances and also of components [8].

Galvao and Sato proposed Function-Task Interaction (FTI) Method. This method includes a general product development process and additionally affordance method, especially FTI matrix [9][10]. In the FTI method, product functions and user tasks were derived from function decomposition and task analysis and then linked to each other in the FTI matrix. The FTI method has been applied in identifying affordances for interior space such as a conference room [11], where affordances for social issues have been addressed beyond function oriented affordances.

Murakami *et al.* tried formulation of affordance feature for product design by experiment with some simple shaped (elliptical-, conical- or rectangular-section) objects which are considered as the control devices. In their research, it was showed that existence of strong relation between some geometric features such as height, aspect ratio between width and length are strongly associated with human action such as pushing, pulling, turning and tilting [12].

In this research, we identified common affordances and affordance features through case studies with some home appliances such as a remote controller, a power screwdriver and a toaster.

## 2 AFFORDANCE FEATURES REASONING

In this research, we define affordance features as structural elements of products that provide affordances. We classify affordance features into functional, ergonomics, and informative aspects, as shown in Figure 1. Functional-affordance features (FAF) are related to the physical properties for behaviors of the object by physical laws. Ergonomics-affordance features (EAF) are related to convenience for operation. Informative-affordance features (IAF) are related to the properties that can help human understand the functionalities and so guide him/her to proper operations.

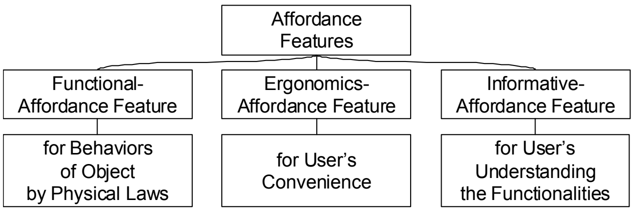


Figure 1: Affordance Feature Classification

## 3 CASE STUDY

The purpose of this case study is to identify common affordances and their affordance features of some home appliances so that these affordance features can be used in designing other products. We selected a remote controller for window blinds, a power screwdriver and a toaster for the case study based on following criteria: 1) commonly used in everyday life, 2) movable, 3) potential for human body action according to user context. The case study products are shown in Figure 2. During this research, we conducted function decomposition and user task analysis. Following them, we combined the sub-functions with user tasks as well as actions in the Function-Task interaction matrix for identifying affordances. And feature reasoning is conducted with respect to affordances identified as shown in Figure 3.

(a) (b) (c)

Figure 2: Products for Case Study; (a) Remote Controller for Window Blinds, (b) Power Screwdriver (c) Toaster

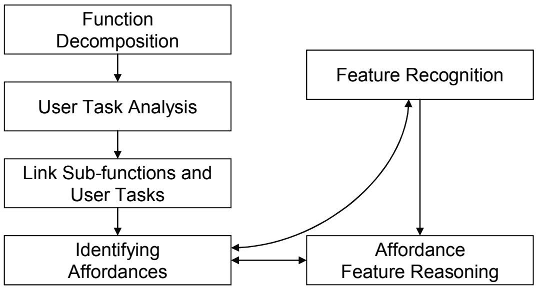


Figure 3: Affordance Feature Reasoning Process

### 3.1 Remote Controller for Window Blinds

3.1.1 Affordances Identification

The overall function of the remote controller (for window blinds in this case study) can be defined as *control window blinds motion*. As a result of function decomposition using functional basis [13], the remote controller (briefly, RC) has three main functions with human hand and hand force as well as electricity being converted into signal as flows. The electricity is supplied from battery by user's pressing action and the electricity is converted to signal which can reach a target object (window blinds) to be controlled as shown in Figure A.(a) of Appendix. From the user task analysis, we get the tasks and actions as shown in the first 2 rows of Figure 4. User holds this device by grasping, orients to the target object in general and then presses a button for starting, stopping rolling motion of the window blinds, or changing direction until the window blinds reaches the proper height. If this device is used inside space where the signal is strong enough to reach the target object, the orienting action may be skipped.

By combining sub-functions with user tasks and actions, we identified *RemoteControl-ability* and *HandControl-ability* consisting of *Grasp-ability* and *Handling-ability*. RemoteControl-ability has *FingerControl-ability* and *Electric-ability* as well as *Signal-ability*. *FingerControl-ability* is composed of *FingerNavigate-ability* and *FingerPress-ability* as shown in Figure 4. *On-ability*, *MovingDirectionControl-ability* and *Off-ability* share same affordances such as FingerControl-ability and Electric-ability as well as Signal-ability as their components.

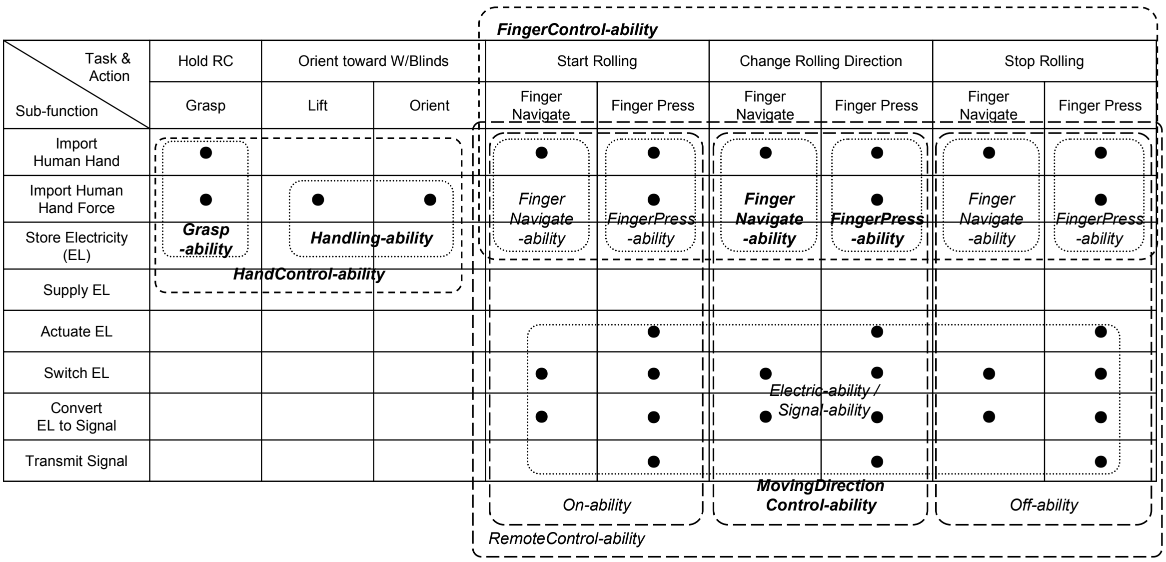


Figure 4: Affordances Identified from Function-Task Interaction for Remote Controller

3.1.2 Affordance Features Reasoning

We recognized affordance features associated with affordances identified in FTI-Matrix as shown in Figure 5. These affordance features are shown in Tables 1 ~ 4 and are classified based on our affordance feature classification shown in Figure 1.

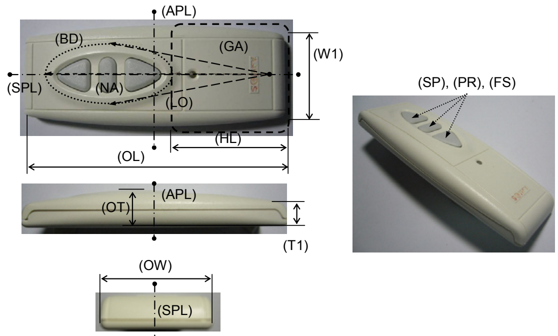


Figure 5: Affordance Features of Remote Controller

For Grasp-ability, a reflective symmetry (represented by symmetric plane, SPL) and a grasping area (GA) are reasoned as affordance features, as shown in Figure 5, where the grasping area is a region contained in a human hand when grasped. The asymmetry (represented by asymmetric plane, APL) caused by location of the button group where one side is too small to afford any grasping, could tell the user how to hold the RC with the correct upright orientation. Note that bad affordances could be given if the RC were symmetric with respect to the plane APL. Due to the symmetry, both left-handed and right-handed persons can equally operate the RC. Grasping area should have proper size accommodating human hand. Thus all affordance features for Grasp-ability are in hierarchical structure as shown in Table 1, and are classified as ergonomics affordance features (EAF).

| ***Grasp-ability*** | | |
|---|---|---|
| ***EAF*** | ● Reflective Symmetric | (SPL) |
| ***EAF*** | ● Grasping Area | (GA) |
| ***EAF*** |   ● Reflective Asymmetric | (APL) |
| |     ● Location of Button Group WRT Grasping Area | (LO) |
| ***EAF*** |   ● Size | - |
| |     ● Length | (HL) |
| |     ● Thickness | (T1, OT) |
| |     ● Width | (W1, OW) |

+ Grasp Type

- Light-tool Grasp

- Thumb – 3 (4) Grasp

Table 1: Affordance Features and Grasp Type for Grasp-ability of Remote Controller

As this product is a hand-held device, we apply a taxonomy of grasping in reasoning about it. A partial taxonomy of grasp was introduced by Cutkosky for manufacturing expert system [14]. Grasp type for this RC is 'light-tool grasp' or 'thumb-3 or -4 fingers grasp' as shown in Table 1. Note that orientation and grasping area are sustained regardless of 'light-tool grasp' or 'thumb-3(4) fingers grasp', due to asymmetry by location of button group.

Affordance features for Handling-ability, FingerNavigate-ability and FingerPress-ability are also shown in Figure 5 and Tables 2 ~ 4. Weight and overall volume consisting overall length (OL), overall thickness (OT) and overall width (OW), are identified as affordance features for Handling-ability, because Handling-ability is related to lifting and orienting actions by human hand force. FingerNavigate-ability has the affordance features of boundary by protrusion (BD) for tactile guiding, size of area inside boundary, and location (LO). Location is further decomposed into position and orientation sub-features with respect to the grasping area, as these are the critical factors in determining whether it is possible to select a button while grasping the RC in one hand.

FingerPress-ability, shown in Table 4, has a protrusion (PR) affordance feature that is physically separated (SP) for pressing. This protrusion has affordance sub-features of height (HT), arbitrary flat surfaces (FS), and size of area accommodating the finger palm. FingerPress-ability has also location with respect to the grasping area. All affordance features of FingerNavigate-ability and FingerPress-ability are classified as ergonomics-affordance features except separation for FingerPress-ability, which is a functional-affordance feature.

| ***Handling-ability*** | | |
|---|---|---|
| ***EAF*** | ● Weight | - |
| ***EAF*** | ● Overall Volume | - |
| - |   ● Overall Length | (OL) |
| - |   ● Overall Thickness | (OT) |
| - |   ● Overall Width | (OW) |

Table 2: Affordance Features for Handling-ability

| ***FingerNavigate-ability*** | | |
|---|---|---|
| ***EAF*** | ● Boundary by Protrusion | (BD) |
| ***EAF*** |   ● Size of Area inside Boundary | - |
| ***EAF*** |   ● Location WRT Grasping Area | (LO) |

Table 3: Affordance Features for FingerNavigate-ability

| ***FingerPress-ability*** | | |
|---|---|---|
| ***EAF*** | ● Protrusion | (PR) |
| ***FAF*** |   ● Separation | (SP) |
| ***EAF*** |   ● Height | (HT) |
| ***EAF*** |   ● Arbitrary Flat Surface | (FS) |
| ***EAF*** |     ● Size accommodating Finger Palm | - |
| ***EAF*** |   ● Location WRT Grasping Area | (LO) |

Table 4: Affordance Features for FingerPress-ability

Affordance features for MovingDirectionControl-ability are shown in Figure 6 and Table 5. A clue for functionality can be provided from difference of shapes (DS) as triangles versus ellipse, which could imply motion and stop respectively. The relative location (RL) of two triangles provides the relative direction. The most critical affordance feature of the RC is that the triangle of the upward-motion button points in the correct (upward) direction when the RC is held as afforded so that this coincides with the upward motion of the window blinds (U-u). To lower the window blinds, the downward button is pressed, as afforded by the triangle pointing downward (D-d). We organize these affordance features as sub-features of the affordance feature *coincidence of configuration and behavior of target object while grasping*. We classified these affordance features as informative-affordance features (IAF).

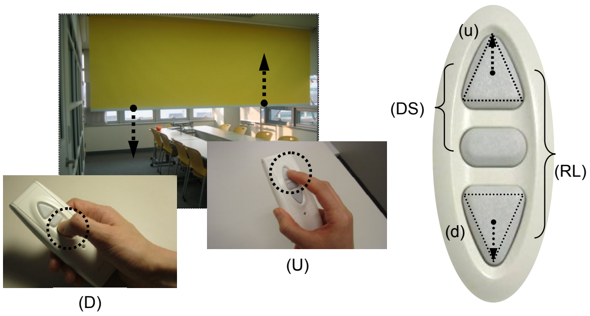


Figure 6: Affordance Features for MovingDirectionControl-ability of Remote Controller

| ***MovingDirectionControl-ability*** | | |
|---|---|---|
| ***IAF*** | ● Coincidence of Configuration and Behavior of Target Object while Grasping | - |
| ***IAF*** | ● Relative Location of Buttons while Grasping | (RL) |
| ***IAF*** | ● Difference of Button Shapes | (DS) |

Table 5: Affordance Features for MovingDirectionControl-ability

### 3.2 Power Screwdriver

3.2.1 Affordances Identification

We now consider the case of a power screwdriver (briefly, PSD). The overall function of a power screwdriver can be defined as *tighten (or loosen) screw*. By decomposing the overall function, we obtain sub-functions as shown in Figure A.(b) of Appendix. A PSD is a kind of screwdriver that uses electric energy for generating torque. Hand force is used only to stabilize the PSD during screwing. Finger force is used to depress the trigger to actuate the electric motor, and to push/pull the switch to change the rotating direction of the screw. Note that adjusting the screw motion should be still operated by human hand even though the PSD is an electric device.

As shown in Figure 7, the user holds the PSD by hand grasping, connects the PSD with a screw by aligning as well as mating, and starts the PSD by pressing the trigger. He/she should select the rotating direction according to the situation or task for either tightening or loosening. During operation, stabilizing and adjusting are sustained by supporting and maintaining the PSD. Generally, the user's other hand should remain free, so that it can be used for finger grasping, lifting and locating a screw at the proper position before being connected and aligned with the PSD.

We identified affordances of the PSD such as HandControl-ability and PowerScrew-ability consisting of Mate-ability, FingerControl-ability, Maintain-ability, Rotate-ability and RotDirectionControl-ability, as shown in Figure 7, from FTI-Matrix. RotDirectionControl-ability has its components such as Electric-ability concerning electricity and FingerPushPull-ability for operations on sliding a switch. FingerControl-ability of this PSD has one more component, FingerPushPull-ability, in contrast to the FingerControl-ability for the RC.

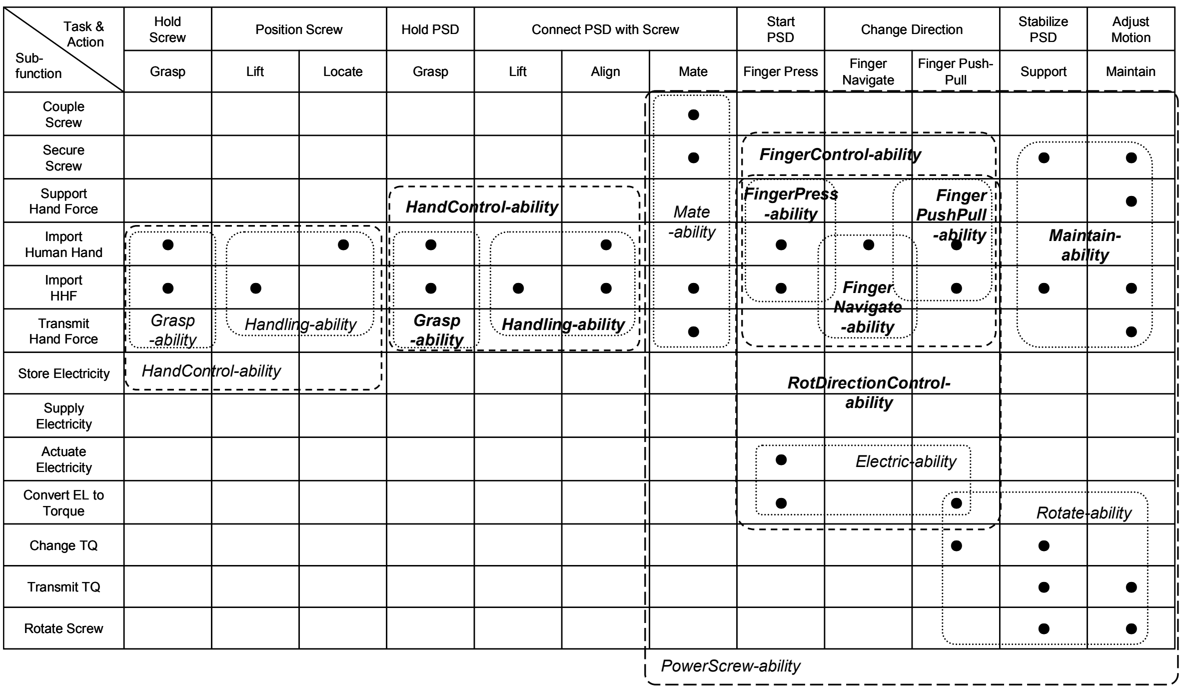


Figure 7: Affordances Identified from Function-Task Interaction for Power Screwdriver

3.2.2 Affordance Features Reasoning

The PSD contains Grasp-ability features of grasping area and reflective symmetry (represented by symmetric plane, SPL), as shown in Figure 8, similar to those of the RC. The reflective symmetry feature allows both left-handed and right-handed persons to operate the PSD.

For FingerPushPull-ability, we identify an affordance feature of a protrusion in a slot, with sub-features of separation (SP), height, two flat surfaces (FS), and location (LO) with respect to the grasping area. Moreover, the two flat surfaces are in opposite directions (OD) along the slot direction. This FingerPushPull-ability is supported by affordance features for FingerNavigate-ability which has boundary by depression (BD) for tactile guiding and size of area inside boundary as well as location (LO). These affordance features in hierarchical relations are shown in Table 6 and Figure 9.

Affordance features for Maintain-ability are shown in Figure 8 and Table 7. The PSD has a hand grasping axis (GX) [15] which does not have to be coaxial to its rotating axis (RX), because screw rotation is caused not by hand rotating motion but by torque converted from electricity. Thus, the human hand need only support and maintain to stabilize the PSD and adjust screw motion during screwing. While maintaining the PSD during screwing, the distance (DT) between the rotating axis (RX) and the arm axis (AX) plays a critical role, because this distance is a functional-affordance feature as the moment arm for resisting reaction force from screwing. The angle (AG) between the rotating axis (RX) and the grasp axis (GX) is also an ergonomics-affordance feature for Maintain-ability, because this angle affects convenience for the person's wrist during the screwing operation.

The containment of the trigger within the grasping area affords stabilized operation to user during screwing. Because the trigger is fully contained in the grasping area, strongly pressing the trigger achieves two functions: it causes triggering, and simultaneously produces strong grasping with securing stability. So this containment is related to Maintain-ability as well as FingerPress-ability falling in our ergonomic-affordance features. The soft rubber (in black color) of the handle is for absorbing impact by reaction force, so it is also identified as an ergonomics-affordance feature for Maintain-ability.

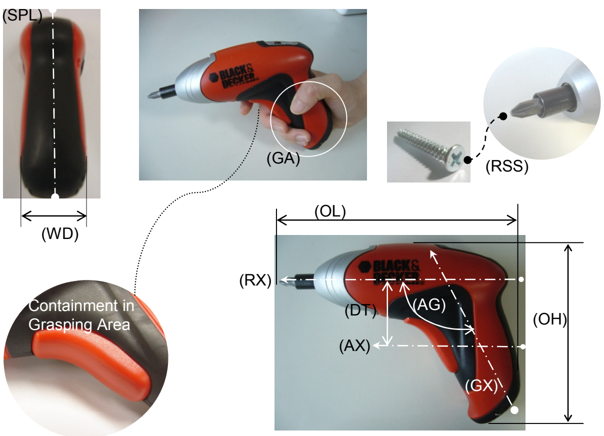


Figure 8: Affordance Features of Power Screwdriver

| | | |
|---|---|---|
| ***FingerPushPull-ability*** | | |
| *EAF* | ● Protrusion | (PR1) |
| *EAF* | ● (Position) inside Slot | (SL) |
| *EAF* | ● Separation | (SP) |
| *EAF* | ● Height | - |
| *EAF* | ● Two Flat Surfaces | (FS) |
| - | ● In Opposite Directions along Slot | (OD) |
| *EAF* | ● Size accommodating Finger Palm | - |
| *EAF* | ● Location WRT Grasping Area | (LO) |

Table 6: Affordance Features for FingerPushPull-ability


Figure 9: Affordance Features for FingerPushPull-ability of Power Screwdriver

In addition, this product has affordance features for Handling-ability, Rotate-ability, and Mate-ability. Because the PSD has the overall function *tighten (loosen) screw*, a rotating axis (RX) exists as a functional-affordance feature for Rotate-ability. Though this PSD has a functionality of interchanging bits, we assumed that a bit proper to context is already installed, so we did not consider Interchange-ability, because Interchange-ability may be equivalent to Mate-ability in the context of our case study. Mate-ability has relative shape and size (RSS) as its affordance features, as shown in Figure 8.

The critical affordance feature of the PSD is the coincidence of the configuration with the behavior of the target object. The configuration for normal operation is the coincidence of a forward direction induced by the forward motion (pushing) of the thumb along a slot when the PSD is held as afforded so that this coincides with the forward motion of the screw (F-f). For unscrewing operation, the slide switch is to be pulled as afforded by backward motion (pulling) of the thumb (B-b) along a slot. Therefore, we identified this coincidence for RotDirectionControl-ability as an informative-affordance feature as shown in Figure 10 and Table 8.

MovingDirectionControl-ability of the RC emphasizes the upward or downward motion of the window blinds, RotDirectionControl-ability of the PSD emphasizes the rotating motion of the bit (sharp tip), which is a component of the PSD itself. This difference in the object being emphasized is due to the nature of an RC as a device using signal without mechanical behavior, whereas the PSD does have mechanical behavior. Therefore, this distinguishes MovingDirectionControl-ability from RotDirectionControl-ability in our case studies.

| | | |
|---|---|---|
| ***Maintain-ability*** | | |
| *EAF* | ● Containment in Grasping Area | - |
| *FAF* | ● Distance between Rotating Axis (RX) and Arm Axis (AX) | (DT) |
| *EAF* | ● Angle between Rotating Axis and | (AG) |

| | | |
|---|---|---|
| | Grasping Axis (GX) | |
| ***EAF*** | ● Soft Rubber | - |

Table 7: Affordance Features for Maintain-ability

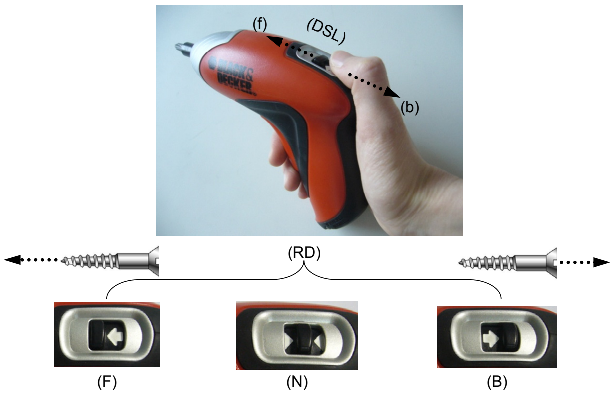


Figure 10: Affordance Features for RotDirectionControl-ability of Power Screwdriver
(N): Neutral Position for Manual Screwing

| ***RotDirectionControl-ability*** | | |
|---|---|---|
| ***IAF*** | ● Coincidence of Configuration WRT Behavior of Target Object while Grasping | - |
| ***IAF*** | ● Direction of Slot | (DSL) |
| ***IAF*** | ● Relative Direction of Arrows while Pushing or Pulling Sliding Switch | (RD) |

Table 8: Affordance Features for RotDirectionControl-ability

### 3.3 Toaster

Toaster (briefly, TST), shown in Figure 2(c), is a kind of home appliances, in contrast to the remote controller and power screwdriver, which are a kind of hand-held devices. TST is generally used on a Table in a kitchen, although it is movable by human.

#### 3.3.1 Affordances Identification

TST has the overall function of *toast bread (bagels)* as shown in Figure A.(c) of Appendix. This product heats slices of bread (bagels) contained in its chamber until they reach the proper temperature determined by the human user according to his/her taste. Because this product converts electricity to thermal energy (heat), emergency or manual stop control exists. As already mentioned, TST is used in a pre-determined place, such as a Table, thus the *Set up Toaster* task generally is not conducted. Furthermore, some users always keep TST plugged into an electric outlet, and may leave the chamber uncovered between uses.

For toasting, the user inserts slices of bread (bagels) down into the heating chamber, and lowers them by depressing a control bar. The user also selects the desired time duration of heating or final temperature. When the temperature or desired time duration is achieved, the toasted bread pops up to allow the user to grasp and lift them. To dispose of bread crumbs that accumulate during operation, the user removes the crumbs by grasping and withdrawing a crumb chamber. These user tasks and actions are shown in the first 2 rows of FTI-Matrix in Figure 11.

We identify many affordances of TST, as shown in Figure 11. Setup-ability allows TST to be set on a place. Wind-/Unwind-ability of cord and Insert-ability of the plug into an electric outlet are identified as sub-features of Handling-ability. Contain-ability (of bread) is composed of Insertdown-ability and Lower-ability. HeatControl-ability is decomposed into Stop-ability, HandControl-ability and HeatSet-ability. Finally, Clean-ability consists of Handling-ability and Accumulate-ability. Additionally, this product has Popup-ability for exporting the toasted bread.

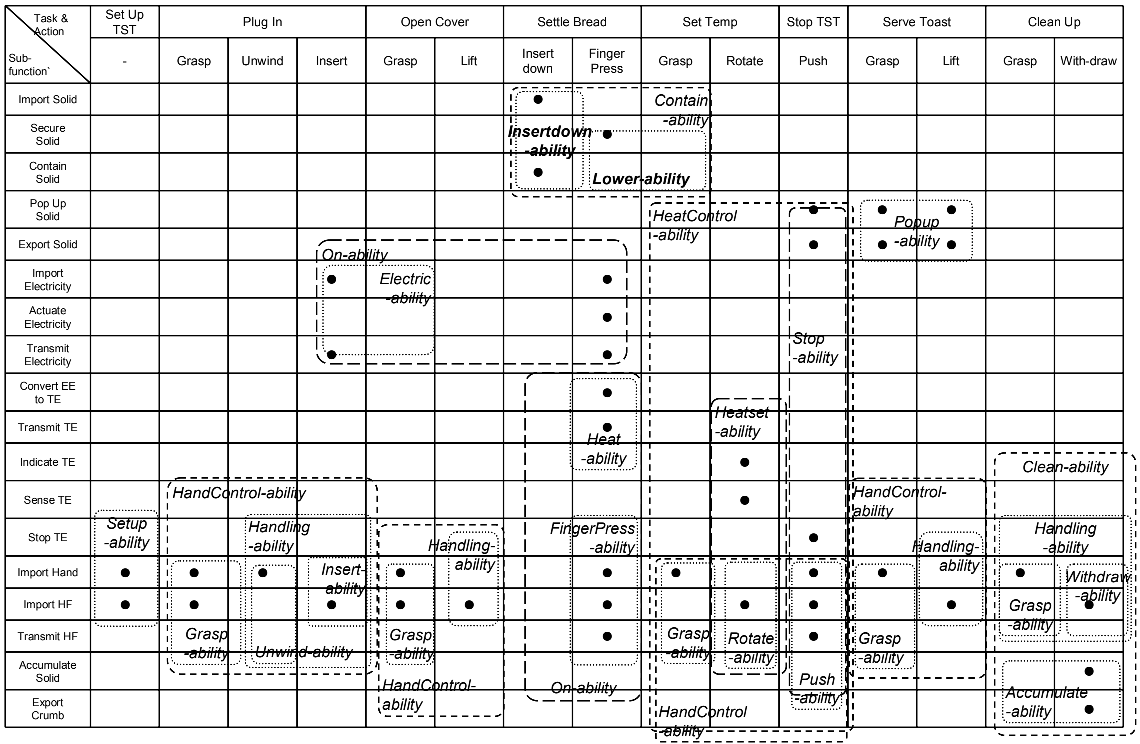


Figure 11: Affordances Identified from Function-Task Interaction for Toaster

3.3.2 Affordance Feature Reasoning

We have identified some very remarkable affordances as Insertdown-ability and Lower-ability. In this paper, we will focus on these two affordances only, and describe their affordance features. Insertdown-ability and Lower-ability are shown in Tables 9 ~ 10 and Figure 12.

The user's downward insertion is guided by the only accessibility direction for the chamber. Thus Insertdown-ability has the affordance feature of *depression with upward opening direction* (UOD). The opening has opening size (OS) for accommodating a slice of bread and depression volume (DV) for containing it. This depression is a pocket form feature as defined in [4], whose accessibility cone comprises the vertical upward direction only, i.e. opposite the downward direction of gravity. The possible mating directions for inserting the bread into the depression are obtained as the complement of the accessibility cone, i.e. vertically downward only. Thus the opening at the top provides a clue for the human's cognitive effort to recognize the Insertdown-ability affordance.

Lower-ability has the affordance features of *initial position of a slide bar* and *downward direction in slot*. The initial position of the slide bar is just below the height of the top of the opening (JB), which affords a human hand to continue a natural downward motion for conducting an additional task or action just after inserting the bread. Thus, this subsequent downward motion of the hand can depress slide bar to lower the breads into the heating chamber. These relations exhibit Gaver's sequential and nested affordances [5].

| ***Insertdown-ability*** | | |
|---|---|---|
| - | ● Depression | - |
| ***IAF*** | ● Upward Opening Direction | (UOD) |
| ***FAF*** | ● Opening Size | (OS) |
| ***FAF*** | ● Depression Volume | (DV) |

Table 9: Affordance Features for Insertdown-ability

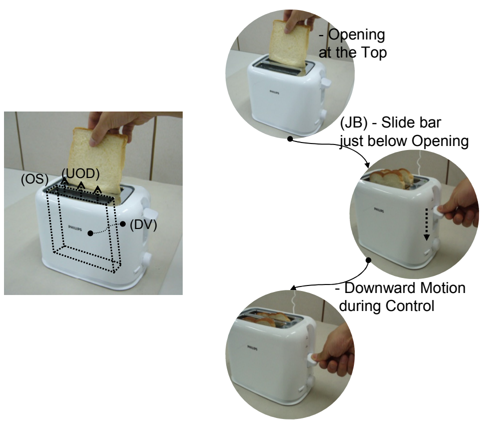


Figure 12: Affordance Feature for Insertdown-ability and Lower-ability of Toaster

| ***Lower-ability*** | | |
|---|---|---|
| ***IAF*** | ● Relative Position between Slide bar and Opening | |
| - | ● Just below Opening | (JB) |
| | ● Downward Direction | - |

Table 10: Affordance Features for Lower-ability

## 4 CONCLUSION

In this research, affordance features are defined as structural elements of products that provide affordances. Affordance features are classified into functional, ergonomics, and informative aspects and are identified in a hierarchical structure.

We have identified some affordances by analyzing hand-held devices such as a remote controller (RC) and a power screwdriver (PSD). Those affordances are HandControl-ability consisting of Grasp-ability and Handling-ability, and FingerControl-ability composed of FingerNavigate-ability, FingerPress-ability and FingerPushPull-ability. For hand-held devices, especially those with controlling functions such as the RC and PSD, the critical affordance features are related to the coincidence between the operations of human hands and the behavior of the object to be controlled. This behavior can be a physical motion of the object, or variation of the object's state, such as a change in temperature. For the toaster as a kind of kitchen appliance, we have identified the affordances of Insertdown-ability and Lower-ability as well as their critical affordance features.

Specific affordance features identified from diverse home appliances could be stored in a repository with a suitable classification scheme regarding affordances and affordance features as well as task context. Such a repository could support the affordance-based design of other devices involving interaction with human hands.

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**APPENDIX: FUNCTION DECOMPOSITION**

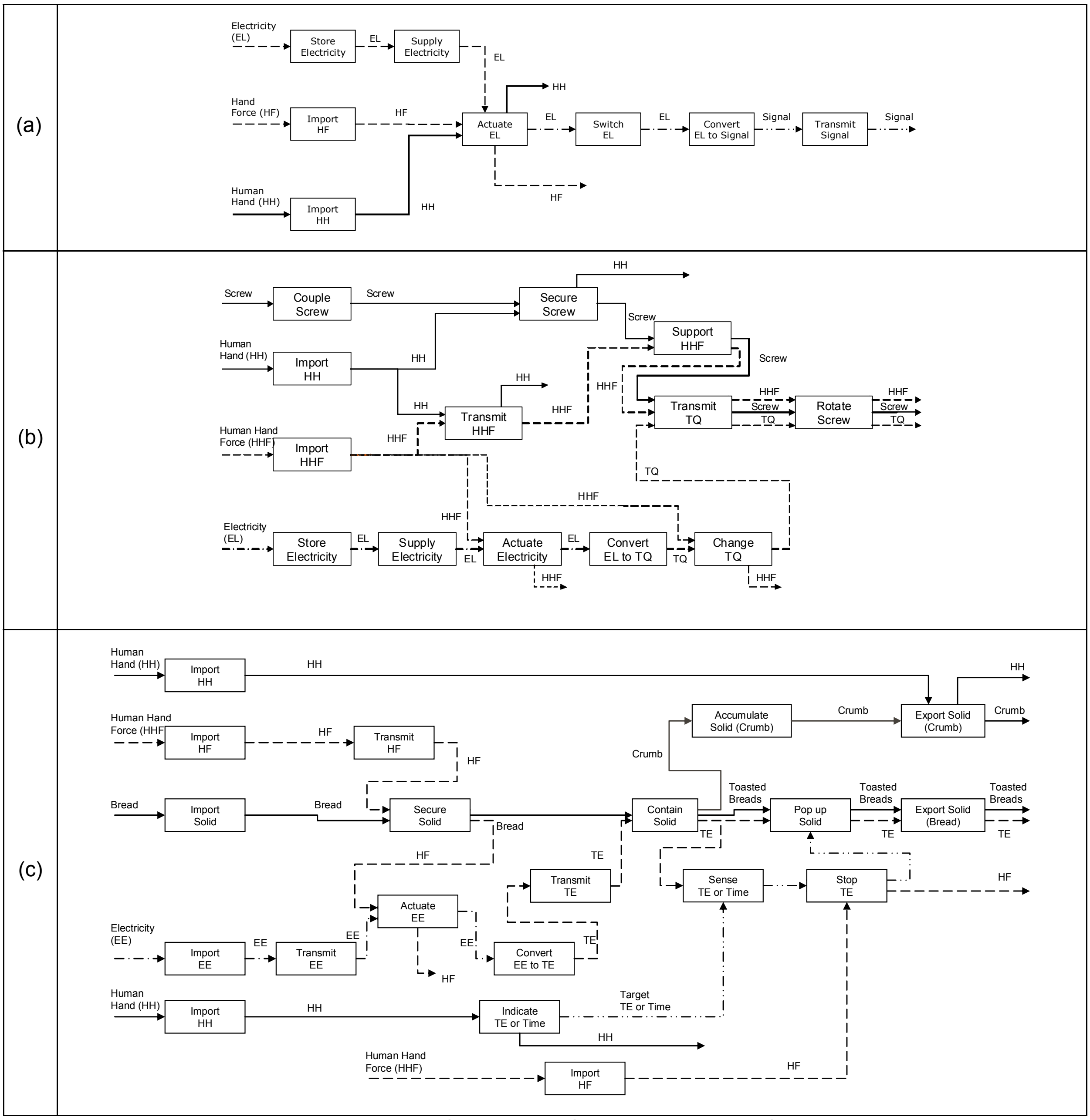


Figure A: Function Decompositions of (a) Remote Controller, (b) Power Screwdriver, (c) Toaster