BlowBrush: A Design of Tangible Painting System Using Blowing Action

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Abstract. This paper presents a novel tangible interaction system called BlowBrush that enables people to create leaf collage paintings on a digital canvas by blowing at a toy windmill. We couple the metaphorical mapping between wind and blow to facilitate the interaction that uses digital leaf inks for drawing. The windmill-shape device functions as a brush that transforms users' blowing and grasping actions into painting commands. Four kinds of digital leaf inks can be used alternately via swapping the physical RFID sheets. Uses manipulate the tangible brush and inks to compose a digital leaf collage intuitively as well as artists. We carefully review the related literature of tangible interaction and abstract the critical criteria as our design guideline. In the end of this paper, we conduct the comparative evaluation to assess the effectiveness between BlowBrush, TouchBrush, and MouseBrush based on the criteria.

Keywords: Tangible User interface, Embodied Facilitation, Affordance, RFID.

1 Introduction

The use of real world metaphor for the intuitive interface design is getting more attention due to the development of HCI (Human-computer Interaction). Instead of designing regular interfaces such as a mouse or a keyboard, the researchers have diverse focus on the concepts of multi-modality rather than uni-modality, target-driven interfaces rather than command-based ones, and finally active rather than passive interfaces [15]. *Embodied interaction* is an approach to understand HCI that apply complex interplay of mind, body, and contextual environment in interaction. Dourish defines the term embodied interaction as a proper way to exploit our familiarity with the everyday world [5]. The way in which we experience the world is through directly interacting with it, and we act in the world by exploring the opportunities for action that it provides to us. Dourish believes the experience that we gain from daily life should be designed as clues to increase our engagement with abstract computing process. This approach usually refers to the *tangible computing* technology due to the shared idea of embodiment. In the article of Tangible Bits, Ishii and his group in MIT design TUI (Tangible User Interfaces) which employ physical objects, surfaces, and spaces as

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tangible embodiments of digital information [12], [13]. Their early project called Urp [37] provides an example to explain how to involve the daily experience in the implement of TUI. In short, people are used to mapping their analogous conventions with unfamiliar stuffs.

This concept called affordance are first proposed by Gibson [7] and appropriated by Norman [18], [19] in the context of HCI. According to Norman's definition, affordance is the design aspect of an object which suggests how the object should be used. In the field of TUI, the concept of affordance is particularly matched with the design of user's interaction derived from the daily experience. However, it doesn't mean all TUIs can carry well affordance spontaneously. Affordance relies on the embodied metaphor [1], which means the associable mapping or connection between things that help us understand one thing in terms of another. In view of intuitiveness approach, metaphorical mapping efficiently borrows the prefabbed knowledge to facilitate the familiarity of new stuff immediately. Therefore, the TUIs with well embodied metaphor may suggest the intuitive interaction without any prior instruction.

In this paper, we propose a novel painting system that uses the natural "*blowing*" action as the tangible interaction tool. The painting system called BlowBrush enables people to create leaf collage paintings on a digital canvas by blowing at a toy windmill. We try to couple the metaphorical mapping between wind and blow to facilitate the interaction that uses digital leaf inks for drawing. We carefully review the related literature of tangible interaction and abstract the critical criteria as our design guideline. In the end of this paper, those criteria of tangible interaction also play the important role for our evaluation. We conduct the comparative evaluation based on the criteria to assess the effectiveness between BlowBrush, TouchBrush, and MouseBrush.

2 Literature Review

Direct manipulation, guided by affordance, is commonly argues to support "ease to use" in terms of tangible interaction [10]. The intention of most of tangible interaction design is to take the advantage of natural physical affordance [19] to achieve a legible and seamless interaction between users and information. This concept highly links to the intuitive behaviors derived from direct manipulation. What makes direct manipulation intuitive is the essential question in terms of affordance applied to tangible interaction. In the following section, we make careful studies and review several researches and projects to reveal the design thinking from tangible manipulation to metaphorical affordance.

2.1 Tangible Manipulation of Digital Information

Shneiderman first used the term *direct manipulation* to refer to an emerging class of highly usable and attractive systems and proposed three principles in 1993 [32]. The concept was originally proposed in the context of GUI (Graphical User Interfaces). Some researchers like Ishii inherited this concept and further applied it to the theory of TUI (Tangible User Interface) in 1999 [35]. Ishii run the tangible media group at MIT media lab and conducted serial researches related to tangible interaction. The early case metaDESK [36] supported interaction with a geographical map through the direct manipulation of several physical tokens. Triangles [8] designed a set of triangle-shape triangle panels for exploring stories in a non-linear way. PuzzleTale [29] made use of tangible puzzle pieces on tabletop surface for dynamic storytelling interaction. In the PuzzleTale system, assembling the tangible puzzle pieces could affect the digital characters and create a flexible story context. Other famous research projects such as Resnick's Programmable Bricks and Crickets [22], [23], Raffle's Topobo [21], and Kaltenbrunner's reacTIVision [14] employed sensible components, assembly robots, and tabletop surfaces as haptic mediations to manipulate digital information directly.

Another approach for direct manipulation regarded the tangible technology as an assisted tool for full-body interaction. Schlömer and his teammates employed the Wii controller to support the sensor-based gesture recognition [27]. Users could define personal gestures to interact with the computer like a photo browsing on a home TV. The Surface Drawing project [26] developed a drawing system that allowed users to draw 3D shapes with bare hands and tangible tools. Tangible Comic [25] created an immersive environment where users controlled their digital avatars in the narrative scene via the full-body motion mapping. Blui [20] supported the hands-free interaction with blowing motion to directly control certain interactive applications. The Sound Maker project [1] allowed users to output ambient sounds according to their full-body input. All of the researches or projects we mentioned above shared the common argument: design tangible manipulation complied with relevant digital information for more *intuitive* interaction.

2.2 Natural Metaphor for Affordance

What made tangible interaction so intuitive? Was "affordance"[19] the consequent result while things were tangible? A keyboard, strictly speaking, was tangible but not intuitive at all. Fishkin argued metaphor [6] was the key chain to which the users' actions were analogous to the real-world effect of similar actions. He cited Bit Ball [22] as a negative sample which had the well tangible interface design but no analogous metaphor mapping.

The mapping between real-world experience and designed actions effectively helped users borrow the prefabbed experience and then apply them to new stuffs directly. That is intuitive affordance coming from. In I/O Bulb project [37], every building model casted a digital shadow corresponding to the real solar shadow. Users moved or rotated the building models to check the inter-shadowing problems. In addition, the graphical wind needles were distributed on the screen surface to visualize the airflow. Those tangible stuffs and visualized phenomena helped users to effectively apply their experience to the interactive manipulation. Another example called I/O Brush [24] used the metaphor of painting brush to trigger the associable and intuitive painting interaction. I/O Brush was a drawing tool which captures real-world colors and textures as the painting materials. Users move the brush over the target material surface and capture its color and texture, and then drew with them on the canvas. Users could quickly engage with the interaction process without training because the tangible brush inherited the metaphorical mapping of general paintbrush functions. Those two projects we mentioned above successfully imitated our natural cognitions and embedded them to target interaction. The invisible connection facilitated the emergence of familiarity to support affordance while we manipulated the metaphorical stuffs.

3 BlowBrush

We present a novel tangible interaction system called BlowBrush [30] that enables people to create leaf collage paintings on a digital canvas by blowing at a toy windmill. The BlowBrush system is inspired by the experience of natural wind-shaped leaf collages. Through the daily experience of nature, people associate leaf collages with wind and blowing intuitively. Using blowing action as a trigger leverages the cognitive benefits of using articulated joints that facilitates mappings and reflections of the real world metaphor [31]. We try to implement people's natural action in the interaction design to reduce the training process and invite more intuitive manipulation. In this paper, we create a novel blowing interaction play to simulate the wind's painting, to bring out one's creative genius, and perhaps to capture a little bit of the glory of the wonderful fall colors on the digital canvas for all to enjoy.

3.1 The BlowBrush System

The BlowBrush system uses the blowing action as the primary interactive painting tool to draw leaf inks in the digital canvas. In order to receive the blowing action and to guide the drawing directions on the digital world, we develop the tangible object that imitates the windmill form. It consists of three parts for drawing command input: 1.Blowing detection, 2.Rotating detection, and 3.Ink detection (Fig. 1). The combination of blowing and rotating detection functions as a tangible brush. There is a microphone embedded in the blowing detection part to measure the intensity of blowing force. With the increase of wind pressure, the opacity of digital leaf ink will deepen progressively, and vice versa. The blowing time duration controls the amount of leaves being painted on the canvas. Secondly, the body of windmill is rotatable to simulate the different directions of wind. A rotating sensor and a microprocessor are embedded under the root of windmill body to measure the degree of rotation. Uses can rotate the windmill body to distribute the digital leaf ink in the target location of canvas.

Leaves are the metaphorical painting ink of our BlowBrush system. Using leaves as painting ink has two advantages. First, it relates our real world experience in the nature to an artful painting interaction. Users can easily recognize the concept of a wind shaped painting by drawing from their daily experience. Secondly, having leaf-shape ink assures a recognizable painting outcome. Users can then focus their attention on playing with leaf-shape stencils without worrying about their painting skills.

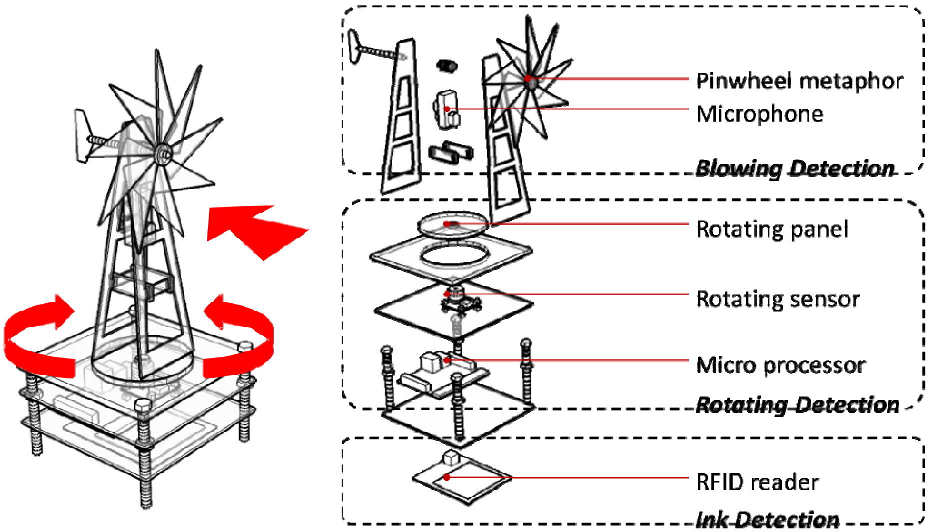

Fig. 1. BlowBrush consists of blowing, rotating, and ink detection functions

Four kinds of leaves (Sugar Maple, White Oak, Hickory, and Sugar Maple) attached on transparent RFID sheets function as different ink categories. Users can choose the target leaf ink by placing the corresponding RFID sheet under the windmill. In addition, they can swap different RFID sheets to change leaf inks during the interaction process just like a real painter doing.

3.2 The Tangible Drawing Interface

The leaf collage painting is instantly displayed on the digital canvas when a user blows at the windmill (Fig. 2). In the initial scene (Fig. 1 left), the canvas shows an image with some footprints and tree shadows on the snowfield to provide the context of a real world environment. When the users start to blow the pinwheel, one kind of digital leaf inks appear on the canvas with different opacities and accumulated amounts according to the blowing intensity and duration. For example, high intensity and long duration renders high opacity and more amounts of leaves. The position of digital leaf inks is determined by the rotation degree of windmill. Users can grasp the windmill body and rotate it in clockwise or anti-clockwise direction to distribute the digital inks in target locations. In addition, users can switch four kinds of painting leaves by putting one kind of RFID sheet under the toy windmill at a time.

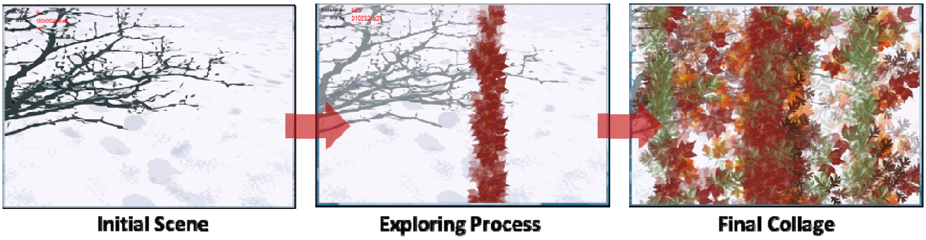

Fig. 2. The digital canvas design and the drawing process

4 Evaluation

The primary goal of our evaluation is to validate the effective design of BlowBrush for the tangible interaction. Some previous researchers have contributed significant works related to the theories and methodologies of tangible interaction evaluation [1, 11, 12, 17, 18]. Here we draw out the critical points of view from those researches and conclude six criteria for the evaluation of tangible interaction. Based on the evaluation criteria we adopt, the comparative evaluation between BlowBrush, TouchBrush, and MouseBrush is conducted with 13 subjects. The quantitative and qualitative results are addressed to provide robust evidences from subjects.

4.1 Evaluation Criteria for Tangible Interaction

In this section we carefully review widespread theories and researches related to tangible interaction and conclude them into six criteria: *Metaphorical Affordance, Enjoyable Engagement, Tangible Manipulation, Spatial Interaction, Embodied Facilitation, and Expressive Representation*. The six criteria not only function as the design guideline for the development of tangible interaction design, but also provide the assessable measures in the phase of evaluation.

Metaphorical Affordance. Affordance is the design aspect of an object which suggests how the object should be used [18, 19]. The essential question is why people have the sense or knowledge to comprehend the manipulation of objects designed by affordance? What makes things intuitive enough? Actually, affordance design borrows the concept of metaphor. Metaphor is the inherent attribute of human derived from the mapping ability of daily experience and new stuffs.

Metaphorical affordance focuses on building the direct mapping and the seamless coupling between pre-existing experience and tangible object design. Then we can take advantage of natural physical affordances to achieve a heightened legibility and seamlessness of interaction between people and information [12, 13]. Based on this view, the critical successful factor is to simulate or duplicate our pre-existing experience and apply it to the tangible interaction design. The appropriation of our daily experience can bring the intuitive behaviors according to the metaphorical affordance.

Enjoyable Engagement. The enjoyment of users plays an important role in the tangible interaction design. If users do not enjoy the interaction process, they will not interact with it [33]. An enjoyable tangible interaction enhances users' engagement via the smooth flow experience and the immersive environment. The relation of the smooth flow experience and the immersive environment is causal and consequent. Once the smooth flow experience is achieved, the immersive environment will be built spontaneously and finally accomplish the enjoyable engagement.

Wyeth defined eight elements for the flow experience in order to evaluate player enjoyment in games [33]. Here we slightly modify his scheme to adapt to the tangible interaction and conclude the following protocol [1, 33, 38]: In the beginning, the tangible interaction needs to set up the clear goal and appropriate challenges which match users' skill level. During the interaction process, users should feel a sense of control and feedback over the tangible objects for the concentration and immersion demands. If the tangible interaction allows multi-users access, the opportunity of social interaction should also be supported.

Tangible Manipulation. The term tangibility means the attribute of being easily detectable with the senses. When it is applied to tangible interaction scenarios, the creature from this concept is generally defined as a tangible object. The tangible object represents the physical object which serves as a special purpose interface for a specific application using explicit physical forms [12]. The tangible object mediates between users and their target digital information and partially shares the similar idea with HCI. However, the critical difference between tangible interaction and HCI is that the tangible object itself is coupled with computational resources to allow users' direct manipulation [11].

Tangible manipulation involves directly manipulating material objects that represent the objects of interest [34]. Users physically grab, feel, and move tangible objects to "interact" (input, output, or both) with target information [9, 11]. In addition, if possible, the manipulation of user and the feedbacks from system should be close bound with tangible objects together to provide the cognitive mapping. This kind of integration bridges the gap between cause and effect and provides legible relations of them. For example, when we design a tangible brush for digital drawing, the slight vibration which simulates the contact of brush and paper should occur on the tangible brush. If the vibration feedback doesn't couple with the brush or replaces by other effects such as a beep from the speaker, the users may have the difficulty to inherit the metaphorical sense from experience.

Spatial Interaction. Spatiality is an inherent attribute of tangible interaction. The tangible objects which are manipulated by users for interaction are embedded in the physical space. Sharlin[28] argues that manipulating tangible objects exploits the intuitive spatial skills of human. He concludes that a good spatial mapping coupling between objects and its task determines the fundamental quality of tangible interaction.

Spatial interaction embeds tangible objects in the real space and interaction thereby is triggered by users' spatial engagement of movement and perception [9, 11]. Here the tangible objects have broader definition which contains the physical parts and their consequent user actions. Both of them are regarded as spatial clues to evoke the spatial experience in order to enhance the intuitive bodily interaction. For example, the boxing machine usually hangs a punching bag from the top of machine. The suspended bag hints users to interact with it rather than any other button on the machine. Furthermore, in some situations like the boxing machine case, users even have the chance to employ full-body movement and perception called full-body interaction [3, 11]. The full-body interaction encourages users to use as many senses as possible. It creates the immerse environment to attract users' engagement of interaction.

Embodied Facilitation. The term facilitation in the tangible interaction field is defined as the interrelated structure of physical space and metaphorical system which prohibits some actions in order to facilitate target purposes [9, 11]. To be more embodied, the term "constraint" replaces facilitation and expresses straightforward about how to design the tangible interaction via embodied facilitation: ease some activities via limiting others. The following question is how could we determine which kind of activities should be blocked and vice versa?

Human has the inherent facilitation knowledge to reason from analogy. This kind of ability is derived from our daily experience and helps us to build the predetermined movement paths. Therefore, the design logic of embodied facilitation only needs to follow the common sense: block and hinder the functions which make people confused and mistaken. The embodied facilitation is supposed to provide the configuration of material objects or spaces affects and directs emerging behaviors [11]. For example, when we design the plug device, triangular shape is better than rectangular one due to the metaphorical mapping. This kind of concept also refers to the Nielson's error prevention [17] and Norman's affordance [18, 19].

Expressive Representation. In tangible interaction, representation has the meaning of the interrelation between physical and digital performances and how users can perceive them [11]. Ishii also uses the term representational significance [13] to express the importance of physical tokens, which embody the abstract system status for users' legibility. Nielsen's heuristics also introduce the criteria called visibility of system status to keep users informed about what is going on, through appropriate feedback within reasonable time [17].

Expressive representation emphasizes the existence of tangible objects. Users need to be aware of the tangible objects and keep utilizing them during whole interaction process. In addition, the legibility of tangible interaction should be built through coupling the uses' action and the system reaction; moreover, keep it perceivable.

4.2 Evaluation Methodology

As noted in Section 4.1, in order to study the performance of BlowBrush in the six criteria, we conduct the comparative evaluation that compares the blow-based interface (BlowBrush) with our familiar commercial interfaces including touch-based interface (TouchBrush) and mouse-based interface (MouseBrush).

The evaluation compares the performance between three kinds of interfaces by the questionnaire. The development of our questionnaire is based on the six criteria of tangible interaction (4.1). For the comparison purpose, each interface has individual section but share the similar questions. The questions in the questionnaire consist of quantitative and qualitative parts. Five-point Likert scale [12] is applied to the quantitative questions with the scale from 1(strongly disagree) to 5(strongly agree). In addition, subjects also can write down their comments under each question to provide us qualitative information. Twenty-one subjects are selected from diverse backgrounds including design, art, computer science, engineering, and material etc. Their ages are distributed in the 18-40 years range. All subjects use touch-based and mouse-based computers regularly or alternatively in their daily life.

4.3 Evaluation Result

We map three diagrams in Fig. 3 right for the further comparison in individual criteria. Through the mapping diagram, we can quickly realize that BlowBrush performs well in the criteria of Metaphorical Affordance, Enjoyable Engagement, Tangible Manipulation, and Expressive Representation. However, in the criteria of Spatial Interaction and Embodied Facilitation, the BlowBrush have approximate or even lower score than other two interfaces (Fig. 3 left: Embodied Facilitation is approximate and Spatial Interaction is lower).

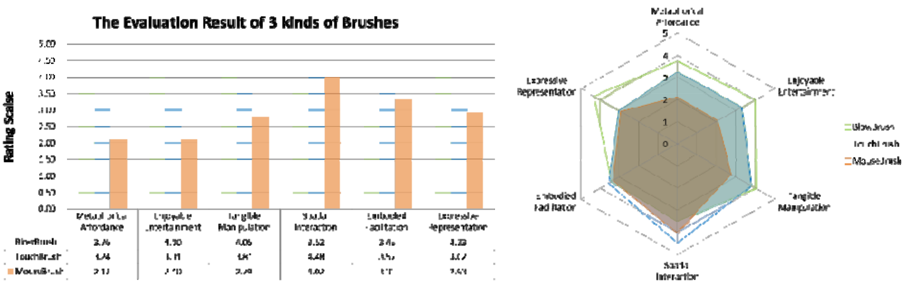

Fig. 3. Left: The bar chart illustrates the comparative scores of 3 brushes in each criterion. Right: The mapping radar chart of 3 brushes

In order to probe into the cause, we retrieve the qualitative feedbacks of subjects in the questions of Embodied Facilitation and Spatial Interaction. For the Embodied Facilitation part, subjects show a lot of interests about the constraint of blowing action. Most of subjects appreciate the limited input method to prevent errors or mistakes triggered by unintentional actions. However, they also say the extra training or practice is necessary due to the unconventional input method. Some subjects expect they can add other natural actions such as gestures and combine them with the blowing action to make interaction more customized.

The BlowBrush interface causes more problems and receives lower score than two other interfaces in the criterion of Spatial Interaction (3.52 v.s. 4.48 & 4.02). Most subjects feel confused about the spatial mapping of digital leaf inks. They believe the

TouchBrush and MouseBrush provide better spatial mapping when they are drawing. While drawing by TouchBrush, digital inks are directly mapped with subjects' finger positions on the screen. The Mouse interface has no direct manipulation on the screen but uses the virtual cursor to locate the targeted area. However, BlowBrush has no spatial mapping or indicator between input and output interaction to assist subjects to locate their target positions precisely.

5 Discussion

In this paper we present the BlowBrush system for interactive painting artistic creation via natural blowing action and assess it through the comparative evaluation. According to the overall statistical result, the BlowBrush (3.82) has higher score than TouchBrush (3.56) and MouseBrush (2.92) in the average score. This result suggests that the overall performances of BlowBrush and TouchBrush are effective for the painting task (over 3 in 5 scales). However, the mapping of radar charts also indicates that BlowBrush and TouchBrush have different superior performances in the six criteria.

The further analysis shows that BlowBrush performs well in the criteria of Metaphorical Affordance, Enjoyable Engagement, Tangible Manipulation, and Expressive Representation. It suggests two primary conclusions: 1. The design of blowing action as the tangible input method successfully associates the nature metaphor with the painting process. Subjects can couple their experience of nature (Wind blows fallen leaves) with the manipulation of tangible interaction (Human blows digital leaf inks). 2. The novel interface successfully engages subjects with fun. Most of subjects show a lot of interests when they play with BlowBrush. The enjoyable interface derived from blowing action keeps subjects engaging in the interaction and enjoying their play. However, BlowBrush may have inferior performances in the criteria of Embodied Facilitation and Spatial Interaction. We try to draw out the causes through the qualitative analysis of subjects' heuristic feedbacks. For the Embodied Facilitation criterion, we believe one of the reasons which make BlowBrush ineffective is familiarity. Subjects generally have sufficient skills to manipulate the TouchBrush and MouseBrush interfaces because two of them have been used in our daily life regularly. Using blowing action as an input method may be unconventional and need extra training or practice. For the Spatial Interaction criterion, the difficulty of BlowBrush is derive from the mapping between the input and output locations. According to the feedbacks of subjects, two potential solutions for the disadvantages in spatial mapping are proposed. First, we can add a clear virtual cursor on the digital canvas to locate the commands from the remote input windmill. Second, maybe we can make the input method more straight via blowing on the digital canvas directly. Of course, the new proposal needs further considerations and tests based on the six criteria of tangible interaction.

References

1. Antle, A.N., Corness, G., Droumeva, M.: What the body knows: Exploring the benefits of embodied metaphors in hybrid physical digital environments. Interacting with Computers 21, 66–75 (2009)
2. Blythe, M., Overbeeke, K., Monk, A.: Funology: From usability to enjoyment, vol. 3. Kluwer Academic Pub. (2004)
3. Buur, J., Jensen, M., Djajadiningrat, T.: Hands-only scenarios and video action walls: Novel methods for tangible user interaction design. In: The 5th Conference on Designing Interactive Systems: Processes, Practices, Methods, and Techniques, pp. 185–192 (2004)
4. Desurvire, H., Jegers, K., Wiberg, C.: Evaluating fun and entertainment: Developing a conceptual framework design of evaluation methods. In: Facing Emotions: Responsible Experiential Design INTERACT 2007 Conference, Rio, Brasil (2007)
5. Dourish, P.: Where the action is: The foundations of embodied interaction. The MIT Press (2004)
6. Fishkin, K.: A taxonomy for and analysis of tangible interfaces. Personal and Ubiquitous Computing 8, 347–358 (2004)
7. Gibson, J.: The concept of affordances. Perceiving, Acting, and Knowing, 67–82 (1977)
8. Gorbet, M., Orth, M., Ishii, H.: Triangles: Tangible interface for manipulation and exploration of digital information topography. In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, pp. 1–8. ACM Press/Addison-Wesley Publishing Co. (1998)
9. Hornecker, E.: A design theme for tangible interaction: embodied facilitation. In: ECSCW 2005 (2005)
10. Hornecker, E.: Beyond affordance: Tangibles' hybrid nature. In: Proceedings of the Sixth International Conference on Tangible, Embedded and Embodied Interaction, pp. 175–182. ACM (2012)
11. Hornecker, E., Buur, J.: Getting a grip on tangible interaction: A framework on physical space and social interaction. In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems. ACM (2006)
12. Ishii, H.: Tangible bits: beyond pixels. In: Proceedings of the 2nd International Conference on Tangible and Embedded Interaction. ACM (2008)
13. Ishii, H., Ullmer, B.: Tangible bits: Towards seamless interfaces between people, bits and atoms. In: Proceedings of the ACM SIGCHI Conference on Human Factors in Computing Systems, pp. 234–241. ACM (1997)
14. Kaltenbrunner, M., Bencina, R.: reacTIVision: A computer-vision framework for table-based tangible interaction. In: Proceedings of the 1st International Conference on Tangible and Embedded Interaction. ACM (2007)
15. Karray, F., Alemzadeh, M., Saleh, J., Arab, M.: Human-computer interaction: Overview on state of the art. International Journal on Smart Sensing and Intelligent Systems 1, 137–159 (2008)
16. Likert, R.: A technique for the measurement of attitudes. Archives of Psychology (1932)
17. Nielsen, J.: Heuristic evaluation. Usability inspection methods 17, 25–62 (1994)
18. Norman, D.: Affordance, conventions, and design. Interactions 6(3), 38–43 (1999)
19. Norman, D.: The design of everyday things. Basic Books, AZ (2002)
20. Patel, S., Abowd, G.: Blui: Low-cost localized blowable user interfaces. In: Proceedings of the 20th Annual ACM Symposium on User Interface Software and Technology. ACM (2007)

21. Raffle, H., Parkes, A., Ishii, H.: Topobo: A constructive assembly system with kinetic memory. In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems. ACM (2004)
22. Resnick, M., Martin, F., Berg, R.: Digital manipulatives: New toys to think with. In: Proceedings of the CHI 1998 Conference on Human Factors in Computing Systems, pp. 281–287 (1998)
23. Resnick, M., Martin, F.: Programmable bricks: Toys to think with. IBM Systems Journal 35(3.4), 443–452 (1996)
24. Ryokai, K., Marti, S., Ishii, H.: I/O brush: Drawing with everyday objects as ink. In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, pp. 303–310. ACM (2004)
25. Samanci, Ö., Chen, Y., Mazalek, A.: Tangible comics: A performance space with full-body interaction. In: Proceedings of the International Conference on Advances in Computer Entertainment Technology, pp. 171–178. ACM (2007)
26. Schkolne, S., Pruett, M., Schröder, P.: Surface drawing: Creating organic 3D shapes with the hand and tangible tools. In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems. ACM (2001)
27. Schlömer, T., Poppinga, B., Henze, N., Boll, S.: Gesture recognition with a Wii controller. In: Proceedings of the 2nd International Conference on Tangible and Embedded Interaction, pp. 1–4. ACM (2008)
28. Sharlin, E., Watson, B., Kitamura, Y.: On tangible user interfaces, humans and spatiality. Personal and Ubiquitous Computing 8(5), 338–346 (2004)
29. Shen, Y.T., Mazalek, A.: PuzzleTale: A tangible puzzle game for interactive storytelling. Computers in Entertainment (CIE) 8, 11 (2010)
30. Shen, Y.T., Do, E.Y.L.: Fun with blow painting!: Making leaf collages by blowing at toy windmill. In: Proceeding of the Seventh ACM Conference on Creativity and Cognition, pp. 437–438. ACM (2009)
31. Shen, Y.T., Do, E.Y.L.: Making digital leaf collages with blow painting! In: Proceedings of the Fourth International Conference on Tangible, Embedded, and Embodied Interaction, pp. 265–268. ACM (2010)
32. Shneiderman, B.: Direct manipulation 97 (1993)
33. Sweetser, P., Wyeth, P.: GameFlow: A model for evaluating player enjoyment in games. Computers in Entertainment (CIE) 3, 1–24 (2005)
34. Ullmer, B.: Tangible interfaces for manipulating aggregates of digital information. PhD Thesis. Massachusetts Institute of Technology (2002)
35. Ullmer, B., Ishii, H.: Emerging frameworks for tangible user interfaces. IBM Systems Journal 39, 1–15 (2000)
36. Ullmer, B., Ishii, H.: The metaDESK: Models and prototypes for tangible user interfaces. In: The 10th Annual ACM Symposium on User Interface Software and Technology. ACM (1997)
37. Underkoffler, J., Ishii, H.: Urp: A luminous-tangible workbench for urban planning and design. In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, pp. 386–393 (1999)
38. Wiberg, C.: A measure of fun: Extending the scope of web usability. PhD Thesis. Umeå University (2003)