Beyond Fingers and Thumbs – A Graceful Touch UI

Elegant Multi-touch and Gesture UI with Context Dependent Prompting

Sue Hessey[1], Szu Han Chen[2], and Catherine White[1]

[1] BT Plc Research and Innovation, Adastral Park, Ipswich UK
[2] University of Essex, Colchester, UK
{Sue.hessey,Catherine.white}@bt.com,
schenr@essex.ac.uk

Abstract. Recent developments in multi-touch screens and gesture based in-air devices provide scope for the design of UIs with multi-digit control. Software functionality choices that were traditionally controlled using buttons on pointing devices can now be selected by different gestures and/or combinations of touches. However, requiring the user to memorize complex gestures can create a barrier to use. In our UI design, we consider it important to aid the users' awareness of their current state of interaction with the system. In this paper we introduce the concept of a UI component called a "*Personicon*" which can be used with multi-touch screens or multi-digit in-air control. We discuss user experience tests of this design with in-air control, revealing the degree to which our novel UI is learnable and the comfort of in-air use. Early results are covered here as a reference for further developments in this area.

Keywords: Gesture, multi-touch, in-air, usability, user testing, UX, UI Design.

1 The "Personicon" – An Introduction to the Concept

A 'Personicon' is an onscreen widget which combines an avatar with a cursor. It is intended for use on multi-touch or gesture controlled screens which can be used by a single user but are also large enough for simultaneous use by two or more people. A Personicon represents an individual user and is the focal point for interactions with the system and with other users. It is controlled by either screen touch or in-air selection – it is the latter on which this paper concentrates. Tracking allows the Personicon to be moved around the screen from its home position, where it can be moved onto or into the active vicinity of other objects. Personicons can also interact with other active Personicons, if multiple users are logged into the same session.

The concept of the Personicon is that it is surrounded by a context-dependent ergonomic menu, designed for multi-digit use (see Fig. 1.). The Personicon menu provides visual prompts to the gesture controls, and its shape and functionality changes with context (preventing the need for gesture memorisation.) The Personicon permits fine control and a natural, graceful interaction with the system and is intended

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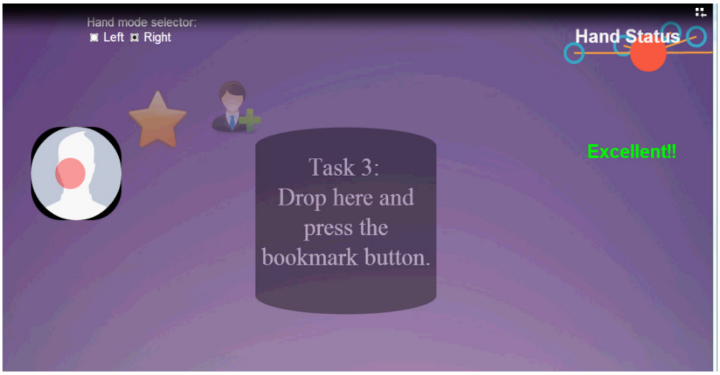


Hand mode selector:
■ Left □ Right

Task 3:
Drop here and
press the
bookmark button.

Fig. 1. Screenshot from user test – the Personicon and ergonomic menu are shown to the left of the “Task 3” box

to reduce fatigue and discomfort in using the system as well as providing an intuitive focal point for each user in a multiuser system.

2 Multi-digit Touch and Gesture Control – A Background

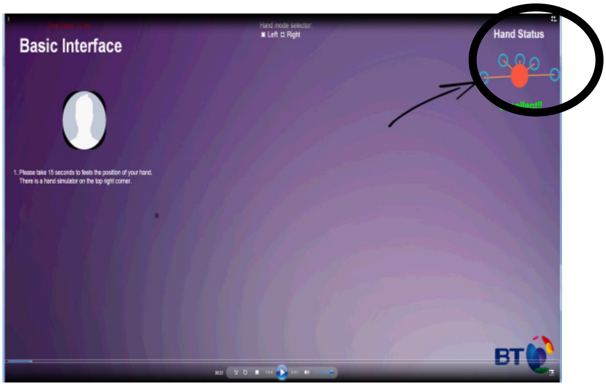
The most commonly applied multi-touch gestures in current consumer devices are forefinger and thumb, e.g. pinch to zoom or swivel to rotate and block multi finger such as “swipe.” Developers of the most successful touch interfaces including Apple iOS and Android have recognised the importance of providing strong visual cues and affordances in the user interface to allow discoverability and prevent the need for excessive memorization. For larger devices which are fixed onto stationary bases, such as the Microsoft surface, 2 hand, 2 forefinger interaction is recurrent and popular in UI design. Even designs for alternative application areas, such as the Lemur Jazz [1-2] mix desk primarily use single point of interaction touch controls, such as button pushes and sliders. Some of the most novel forms of interaction, such as that used by the ReacTable [3-4], have involved the placement and rotation of separate objects on a horizontal surface. However, many consumers have mastered far more sophisticated multi-digit use of desktop keyboards, and this suggests that people have the potential to interact with their multi-touch devices with more elegance and grace. Can similar levels of grace be used at surfaces which are vertical or inclined, and by people interacting in a more casual way, for example while standing up?

Very recently, the Leap motion controller [5] has made the possibility of individual digital control from in-air gesture a possibility for users. This provides a novel method of adding gesture control to an application using hand movements over the screen. This method provides some advantages over touch kiosks, such as low cost, speed of movement, hygiene. However the novelty of the interface, technical limitations such as limited range and view of the device, and the lack of physical support from touching the screen may cause difficulties. We explore the success of this interface through the user tests described in this paper. We performed usability testing of in-air multidigit control of a user interface where users held their hands in a horizontal position while seated. In-air gestures were multi-"touch"-like, consisting of dragging parallel to the screen in combination with tapping/pushing with in a direction with non-zero component perpendicular to the screen, however in these tests no physical contact was made to the screen.

3 Technical Details of the Prototype

3.1 System Overview

Our test system is a standalone web-based application, providing two types of gesture control: five finger mode and one finger mode, which is represented by a visual indicator displayed on the screen (see Fig. 2.).



1. Please take 15 seconds to feels the position of your hand.
There is a hand simulator on the top right corner.

Fig. 2. Screenshot of the user test with the visual indicator – shown here in 5 finger mode – in the top left

Five finger mode requires the user to place one of their hands horizontally above the Leap motion controller with 5 fingers outstretched. With one finger mode, the user is required to place one of their hands above the controller with one finger visible to the detection range of the sensor by "pointing" with the index finger. A multi-touch option is displayed on the "Personicon" in five finger mode (see Fig. 1.). The second and third fingers (i.e. middle and ring) are used to activate a selection. In one finger mode, a "tap" action by the index finger registers a click in the number pad task (see section 4), but a "prod" makes the selection in the clicking task.

This application was developed as a web front-end application executed in a web environment. Most operations are processed locally, with the client side requesting server connection from a local server. A centrally operated JavaScript file runs after the connection is made between the browser and the local server. jQuery UI was used to develop the user interface, which updates the position of the visual indicators including the Hand Status, basic pointer, and the Personicon if currently under control.

3.2 System Operation of Different User Interaction Modes

Five finger mode was developed using the JSON coordinate data received from Leap motion controller. To apply the concept of multi-touch into the gesture system, identification of each individual finger is essential. The system sorts the fingertip's coordinates in ascending order within an array based on the x axis of each fingertip and assigns a specific identification number to each sorted fingertip (t0-t4) where t0 represents the thumb, t1 represents the index finger etc. Only the index finger in one-finger mode has a visual indicator. Other fingers' coordinates are captured for carrying out multi-touch tasks.

One finger mode controls the visual indicator by using the position of the palm of the hand. Based on coordination information received from five or one finger mode, the system uses a gesture model to transfer a set of hard-coded logic into events including click, multi-touch options and tap.

3.3 Leap Motion Technical Limitations

The Leap motion controller provides excellent accuracy in position detection, claimed by the manufacturer to achieve up to 0.01mm precision in fingertip position, and independently verified to achieve at least 0.2mm accuracy in static and 1.2mm in dynamic setups, which is of the same order of magnitude as normal hand tremor.[6] However, coordinate data received from the Leap motion controller is generally "noisy" i.e. subject to interference and fluctuations which affect stability and accuracy. The Leap motion controller cannot identify separate fingers if they are too close to one another, and because the Leap cameras are both in the same plane, a single Leap controller cannot accurately measure all the parameters of a hand held at right angles to the controller face.

Another issue is that of time latency delay, or "lag". The Leap motion has a fast frame rate configuration capable of over 200 frames per second with minimal lag. The Leap.js Javascript library provides the loop method which polls the Leap producing approximately 60fps.[7] In addition, a function from Leap.js called "stabilizedTipPosition" was used to achieve a smoothing and stabilization of the 2D contents (coordinates) from the Leap to reduce tremor. This provides a signal that is significantly more stable but that "*lags behind the tip position by a variable amount...depending ..on the speed of movement."*[8] These lags were observed during development of the system and during user testing.

4 User Testing

4.1 Physical Set-Up

The tests were conducted with the participant seated at a table in front of the laptop PC with a screen size of 14 inches and the Leap motion sensor positioned so that their hands and arms were within range of the sensor without making them overstretch or feel restricted in movement.

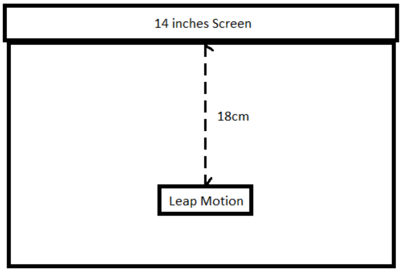


Fig. 3. Diagram showing the aerial view of the hardware set-up. The Leap sensor rests on the keyboard of the laptop.

Some participants adapted their position to suit themselves. The system was switched between right-handed and left-handed mode as needed by the participants. All tests were video-recorded so that the researchers could a) record the interactions with the system and make notes, b) to record the participant's comments on ease of use/problems experienced and general impressions of look and feel and c) the interactions were also recorded from the screen itself to record the movement of the cursor and Personicon, the hand image and the user actions carried out in order to complete tasks.

4.2 Participants

The researchers adopted a "guerrilla"-style approach to recruitment [9] whereby the participants were engaged verbally before the experiment, and that the tests were conducted "on the fly" to fit in with busy work schedules. The tests were deliberately short in duration, and occurred almost instantly after the participant gave their consent so that there was little time for them to gain any other experiences or knowledge of interacting via in-air gesture control, allowing them to participate without any bias towards the system.

The tests were conducted over 3 sessions, which we refer to as batch 1-3. The first two batches consisted of employees within BT's research department, although 2 occupied clerical (rather than research) roles, and only one had any background in usability/ergonomics. These two batches had 13 participants in total, 7 were male and 6 were female. Ages within this trial group were between late 20s and 61. This group made up the first and second batch, and their tests were conducted in an office setting. The other 4 participants (the third batch) were students aged 20-23, all of which were studying a technical degree. Tests for the third batch were conducted within a university setting. Therefore there was considerable diversity in the trial population, even though it is small. However, it should be noted that all of the trial population were able to type, and therefore probably have greater dexterity than the general population.

We conducted the user tests under the assumption that all participants had experience of using touch-screen interfaces which are common in their working and leisure environment.

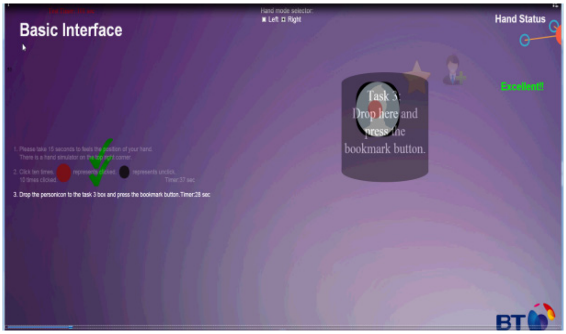
4.3 User Experience Test Outline

A combination of subjective experience capture and timed-task testing was carried out in order to gain a deep level of understanding of the participants' reaction to the UI which was novel to them, and specifically how memorable and learnable [10] it is. Questions were semi-structured to allow for free expression of experiences covering issues such as how obvious the UI was and whether tiredness in the arm was experienced during the test. The UI of the test itself gave instructions on the screen of what the participant was expected to do, in the same order for each test, in an automated sequence.

During the test itself, participants were asked to imagine an invisible wall which the hands should not cross in order for the Leap sensor to work properly. Subsequently, the first task which the participants were asked to complete was to calibrate the range for the Leap sensor, by the participant pointing at a dot on either side of the screen.

The timed tests involved the following tasks:

1. In-air click activation. This involved using a pointed index finger to "click" the cursor by making backwards and forwards motions towards the screen "in-air".
2. Using the whole hand, in-air, to select and move the Personicon, and to "drop" it into the box shown on the screen (Fig. 4.). Participants were asked to "drop" the icon with their hand gestures in whatever way felt intuitively correct to them.
3. Using second and third fingers to select bookmarks and contacts icons while the Personicon is selected by the in-air position of the whole hand (the bookmark and contacts icons are highlighted by becoming larger when selected)
4. Using one finger to "tap" numbers on a keypad (in-air "tap" gesture).



Task 3:
Drop here and press the bookmark button.

1. Please take 15 seconds to feels the position of your hand.
There is a hand simulator on the top right corner.
2. Click ten times. ● represents clicked. ● represents unclick.
10 times clicked. Timer:37 sec
3. Drop the personicon to the task 3 box and press the bookmark button.Timer:28 sec

Fig. 4. "Dropping" the Personicon into the box

The test was completed twice to see if there were variations in task times between them and each task was timed, apart from the first (calibration) and last (number pad exercise) which were not recorded as the time spent conducting these activities was deemed least relevant to the overall test.

Before the start of the test, the researcher gave a brief overview of the limitations of the system and instructions, for example explaining the hand status image in the top right corner (see Fig. 2. – the hand status image is ringed), but mainly left the participants to try the interface (Fig. 4.) for themselves to discern what came naturally to them at the beginning of the test. Between the first and second test the researcher then gave some further hints and tips on how to interact with the system.

5 Results – Quantitative

5.1 Learnability

The following graphs show the task times of the 1st and 2nd tests as carried out by the first two batches of participants.

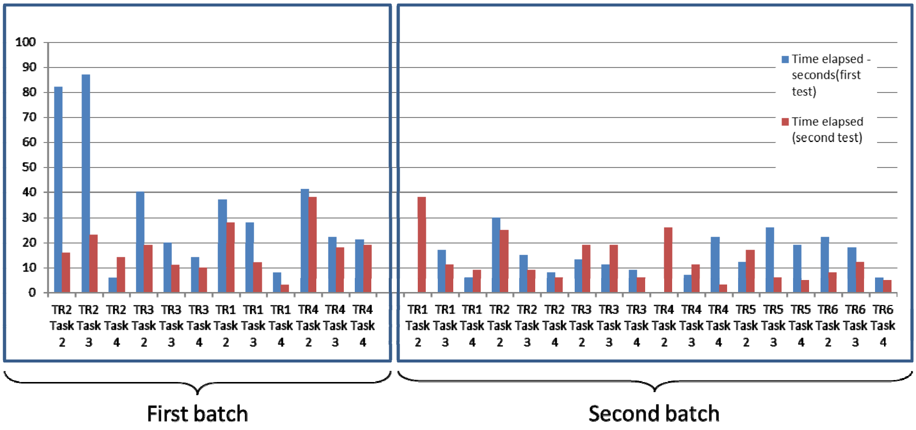


Fig. 5. Timings between first and second tests, and between batches of participants

Results indicate that the system was learnable, demonstrated in reduced task times in the majority of cases (see Fig. 5.). The average task times for the first two batches of participants showed a marked reduction between the first and second tests, that is:

- First test 23.1 seconds per task on average
- Second test 13.6 seconds per task on average[1]

Between the first and second batches there was a slight change to the orientation exercise which preceded the test itself whereby the researcher gave one minute for the participant to orient themselves to select the cursor based on moving the second and third fingers of the hand. As a result the average task times of Batch 2 were around half those for Batch 1:

- Overall average task time (first and second tests) for Batch 1 = 25.7 seconds
- Overall average task time (first and second tests) for Batch 2 = 12.9 seconds

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[1] We discounted those tasks where the timings were unavailable or were altered due to system problems. These instances were in the minority of cases. The average figure was taken across all usable timings.

It is also noteworthy to compare the task time results from Batch 1 and 2 (Fig. 5.) with those of Batch 3 (Fig. 6.). The key differentiator between these two participant groups is age – Batch 3 was entirely comprised of university students, on computing degree courses, aged between 20 and 25, whereas those in Batches 1 and 2 were mostly age 40+.

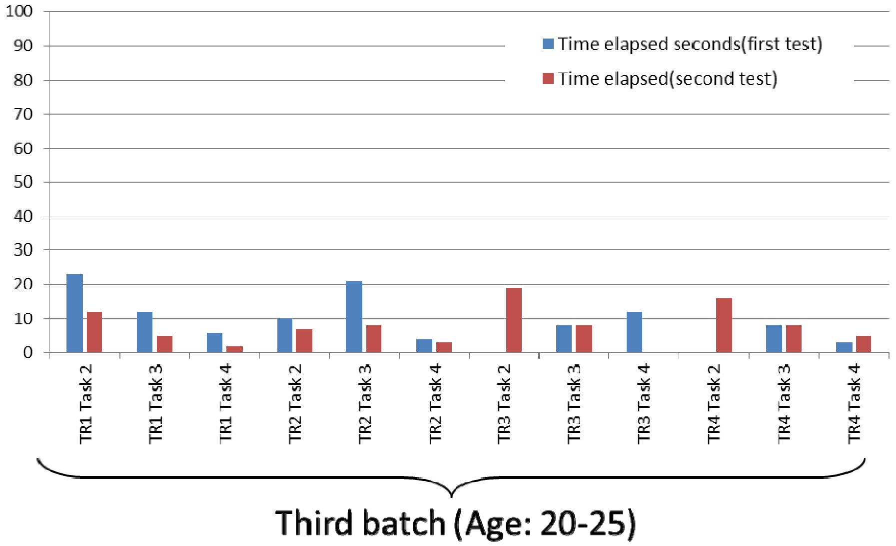

Fig. 6. Timings between first and second tests for university students

Again, in the majority of cases the time taken to complete the tasks was less in the second test than in the first, implying that practice – even just one interaction with the system – makes it easier to use. For this group of users the overall average task time is significantly less than that for Batch 1 and Batch 2 at 8.25 seconds (compared with 25.7 seconds for Batch 1 and 12.9 seconds for Batch 2). This may be significant as age affects an individual's mental processing capability, so this factor will need consideration when developing the interface further for all age groups [11].

6 Results - Qualitative

As part of the test, we also asked the participants subjective questions to discern their opinions of using the system for the first time. The main findings of these discussions are as follows:

Range of in-air device – visual and/or audio feedback requirement.
Participants commented that they needed visual and/or audio feedback of the range of the sensor, as it was easy to move their hand out or close to the edge of range without realizing that they had lost full control of the system.

Selection using the second and third fingers.
All participants found making selections based on moving the second and third fingers, and the movement of the Personicon using the whole hand easy, and these were observed to be smooth, elegant movements, which gave a sense of satisfaction to the participants. One was observed to be distracted by moving the second and third fingers and the effect it had on the icons on the screen, clearly enjoying the exercise.

Novel hand actions for grabbing, dragging and dropping.
Dragging and dropping of the Personicon using the whole hand in-air was smooth and obvious to the participants. At least two participants used a "grabbing" action to select the Personicon object, and "released" the object by bringing the hand away from the screen and/or opening the fingers, in effect seemingly "dropping" the Personicon onto the area where it was intended. This appeared to be intuitive and enjoyable as an interaction method – although this behavior had not been anticipated, and was not the designed mode of interaction.

Hand status image.
A hand status image was provided at a fixed position in the top right of the screen to provide the user with an exact visual model of the current detected state of the hand and the number of outstretched fingers. On the whole, participants found the hand status image a useful reference for the participants to orientate their hands. Only two participants experienced any confusion between the Personicon (its home position being top left) and the hand status image (Fig 3. Top right).

Participants needed reminding of how to position hands and fingers.
Two participants made a "hooking" action of the finger as opposed to keeping finger outstretched to make "tapping" action, especially in the number pad exercise. Other participants held their hand naturally at a 45 degree angle rather than flat and horizontal. On occasion participants' hands and fingers were held outside the range of the sensor (usually too low) for it to register, and some found it difficult to keep hands behind the "invisible line".

Variations in user action to perform task.
Different methods of selection – "pushing" and "tapping" were used during the test, using a combination of one finger mode or five finger modes. It was not always obvious to the participants which one was to be used. This needs to be more obvious in other designs or consistency developed between the methods of interacting across tasks. However, within tasks, the context-dependent menu was intuitive and easy to navigate.

Posture and comfort for short term use.
Some participants intuitively moved to a position most comfortable to them without detracting from the usability of the interface, suggesting that gesture control should be highly adaptable to be usable by all users, potentially in either seated or standing positions.

Some participants commented that they would not want to keep an arm in one position for a sustained period of time, predicting that there would be "tension" in the arm, aching and tiredness. But for short-term use there would not be any perceived problems. A natural workaround was adopted by many participants - many rested their arm on the table intuitively as they would while operating keyboard and mouse.

Summary.

Within the trial population, no issues of difficulty or discomfort were reported while using the whole hand to move the Personicon. This is also the case moving the second and third fingers to make selections for bookmarks and contacts, implying that the movement was not uncomfortable and the level of visual feedback given to the user for these actions was sufficient (i.e. highlighting the items selected by making them larger). The actions of the gesture control were easily learnable.

7 Conclusions

On the whole, participants found the system moderately obvious to use from the outset, with the university students (who like the older groups had no previous experience of in-air gesture control) in particular easily learning and using the system, suggesting younger age groups may engage with in-air gesture control more readily than older groups. Our results indicate that this style of in-air multi-"touch"-like gesture control is easy to learn – there was marked reduction in task times between the first and second tests. Being able to experiment, "play", learn, practice and receive instruction (either pictorially or by following verbal instructions) was important to the vast majority of participants and aided memorizing of what happens during the interactions. Most were genuinely interested to see how the project develops. Two participants considered the interface to be "*fun*" "*It's cool...incredible fun to play[with]*".

The independent use of the first, second and third fingers to control the moveable Personicon and associated ergonomic menu was found to be relatively easy by all participants. This is interesting because this mode of interaction is not a common feature of current user interfaces for true multi-touch screens but could be used to provide users with faster, more sophisticated and less clumsy interactions with systems and devices. It is probably significant that in these tests the screen does not have to be held or supported by the user (unlike a smartphone or tablet) and has a much larger form factor, which allows the user greater freedom of movement when engaging with it.

For short periods of time in-air control is deemed satisfactory, (which is consistent with the intention of the researchers to apply the interface to a shared kiosk intended to support use for short time durations). Many participants adopted workarounds to find a comfortable position (moving the sensor, moving the chair, resting arm on the table). The results of the user trial were promising, however we recognize that in order to draw conclusions about the suitability for the general population we would need to expand the trial population to include those who do not use computers regularly and are unable to type.

Despite the fact that participants were able to operate the in-air user interface under test, they demonstrated a continued preference for touch screens, possibly due to familiarity but also because "*…once you press down on a touch screen you know it [has] registered a click, and it's much more reliable rather than judging the distance in-air.*" Touch-screens also provide a "frame" for operation of the system, which our implementation of in-air control currently does not offer. This will need addressing in subsequent iterations. Further research on inclusive aspects of the system need addressing in future work, in particular with regard to accessibility and adaption for those with motor disabilities and visual impairments.

8 Discussion

In-air gesture control could easily be adopted by the mass market for use in the home, in public or within organizations. In terms of application in business multi-touch, in-air control may be applicable to interactive kiosks in development such as Crowdsense [12]. Similarly, it can be used as an interaction method in consumer devices which are designed for leisure or for utility within the home. At the moment Kinect is widely adopted as a way of interacting with the X-box, so there is already widespread adoption of basic in-air gesture control in gaming systems which can be built upon within the consumer market. Similarly it was suggested in user tests that a more finessed version of in-air operation of the TV (compared to current basic in-air controls offered by the Samsung UE55ES8000 for example) could be developed. When developing new products, any investments in new UIs should be balanced against potential sales revenue, also bearing in mind any potential exclusions presented by the UI [13]. The selling point of a new UI such as in-air gesture control over existing interaction methods therefore needs to be clear to customers. In these contexts, the Personicon, the associated novel UI and its benefits discussed here (e.g. pleasure of use and learnability) may be the vital components in future business propositions.

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References

1. Kellum, G., Crevoisier, A.: A Flexible Mapping Editor for Multi-touch Musical Instruments. In: Proceedings of the International Conference on New Interfaces for Musical Expression (2009)
2. JazzMutant - Lemur, multi-touch modular controller for sequencers, synthesizers, virtual instruments, vj and light, `http://www.jazzmutant.com/lemur_overview.php`
3. Reactable - the electronic music instrument, the App and DJ tool, `http://www.reactable.com/`

4. Jordà, S., Geiger, G., Alonso, M., Kaltenbrunner, M.: The reacTable: Exploring the Synergy Between Live Music Performance and Tabletop Tangible Interfaces. In: Proceedings of the 1st International Conference on Tangible and Embedded Interaction, pp. 139–146. ACM, New York (2007)
5. Leap Motion, Mac & PC Motion Controller for Games, Design, & More, `https://www.leapmotion.com/`
6. Weichert, F., Bachmann, D., Rudak, B., Fisseler, D.: Analysis of the Accuracy and Robustness of the Leap Motion Controller. Sensors 13, 6380–6393 (2013)
7. Leap Motion Developer, `https://developer.leapmotion.com/leapjs/api-guide#Leap_loop`
8. Pointable — Leap Motion 1.0.9 documentation, `https://developer.leapmotion.com/documentation/java/api/Leap.Pointable.html`
9. An Introduction to User Research Techniques — Government Service Design Manual, `https://www.gov.uk/service-manual/user-centered-design/introduction-to-user-research.html`
10. Heuristics for User Interface Design: Article by Jakob Nielsen, `http://www.nngroup.com/articles/ten-usability-heuristics/`
11. Hasher, L., Zacks, R.T.: Working Memory, Comprehension, and Aging: A Review and a new view. Psychology of Learning and Motivation 22, 195 (1988)
12. Hessey, S., White, C., Thompson, S.G.: Initiating New Communications and Collaborations between People in a large Organisation. In: Proceedings of HCI International Conference (2014)
13. Exclusion calculator - Inclusive design tools, `http://www.inclusivedesigntoolkit.com/betterdesign2/exclusioncalc/exclusioncalc.html`