Personal Space: User Defined Gesture Space for GUI Interaction

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Abstract
Reality-Based Interaction (RBI) [14] theorizes that realistic user interactions (UIs) are effective because they exploit users' pre-existing knowledge about their bodies and objects in the world. Gesture based interaction allows users to relay information to a computer through body movement without physical contact with additional hardware such as a mouse or trackball. However, this interaction style requires the users to interact in a manner that is tailored for the system to recognize with very strict rules for bodily interaction, not toward a gesture space that is more natural for the user. In this paper we propose a natural method of gestural input through a user-defined 3-dimensional space. We conducted two pilot studies to assess the performance and usability of these augmented gestural pointing methods for cursor manipulation as compared to a standard mouse interaction as well as the current standard approach used in gestural input.

Author Keywords
Hand tracking; user interface; gestural pointing

ACM Classification Keywords
H.5.2. User Interfaces: Input devices and strategies (e.g., mouse, touchscreen)

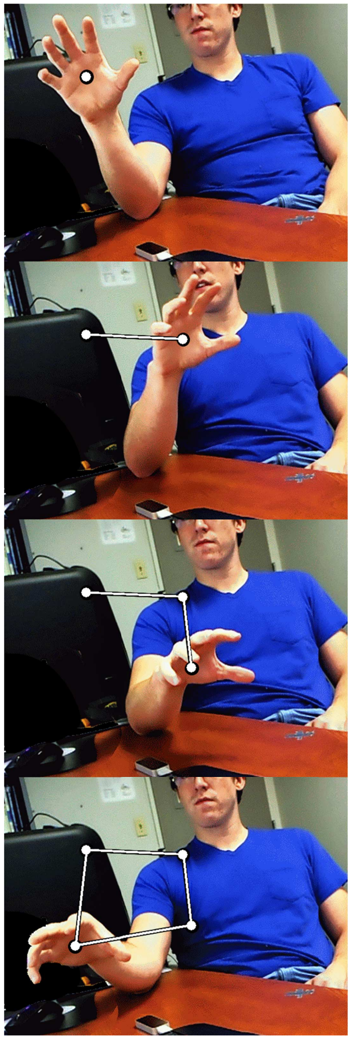

Figure 1. A user defining his gesture space during calibration.

1. Introduction

Since the graphical user interface became the default user interface of personal computers, most input was done with users manipulating some input device with their hand (e.g. keyboard, mouse, etc…). However, in the last twenty years, with the development of new interaction techniques, researchers have begun investigating using free-hands and gestures for user interaction. This type of interaction tends to be an effective, intuitive, and natural interaction way for users to relay information to the computer [12].

One problem that plagues gestural input is referred to as the "Gorilla Arm Syndrome" [10]. Typically, designing a gestural input involves requiring the user to hold their arm(s) out in an unnatural position, causing shoulder and arm fatigue quite quickly. As interaction time increases, this fatigue can lead to poor user performance, physical discomfort, and decreased accuracy.

Figure 2. De facto gestural input (left) and Personal Space (right).

We propose an ergonomic interaction style that allows the users to manipulate the cursor, using their hand as a pointing device without the discomfort associated with Gorilla Arm Syndrome. This approach – henceforth referred to as "Personal Space" - involves having the user rest her elbow on a surface, while controlling the position of the cursor based on the position of her palm. In this position, the user's range of motion is not naturally a rectangle (Figure 1) and therefore does not directly map to the screen. Through a calibration phase, the user defines his preferred space to be mapped to his screen space. This space will not be a right-angled rectangle, and will not be an absolute map to the computer screen (Figure 1). In our experiments, we prove that this non-linear mapping works just as well as a relative map in a right-angled rectangle space, but with significantly less reported fatigue.

In this paper, we describe two pilot studies to assess the performance (task completion time) and usability (self-reported fatigue) of this augmented gestural system for cursor manipulation as compared to a standard mouse interaction and the current standard approach for gestural input. Additionally we will discuss the implications and the direction of future research.

2. Related Works

2.1. Gesture-based Interaction

The application of gesture based interaction has been explored for over 3 decades, the first of which [4] used a multi-modal interaction style, where gestures were used only for pointing while actions analogous to pointing and clicking were done with voice commands. More recently, the application of gestures were shown to be a suitable mode of interaction with very large displays [3], while [5] shows that gestures are useful

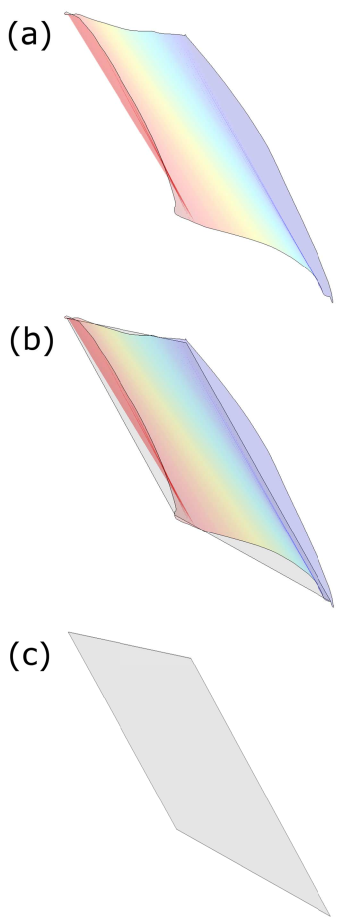

Figure 3. (a) Diagonal view of the arm's natural range. (b) Building a flat plane for Personal Space based on the natural range. (c) Actual flat plane built for Personal Space.

for interacting with the everyday desktop, and [16] shows how RBI themes used in gestural input can lead to higher accuracy. While gesture based research has traditionally revolved around the recognition of gestures and the various poses of the palm, the availability of commodity hardware with open SDKs such as the Leap Motion and Microsoft Kinect® has allowed a shift towards interpretation and application of gestures such as [6] and [7].

2.2. Barehanded Interaction

The "Come As You Are" design principle [8] states that users should not be required to wear a glove or specific markers to interact with the system [12]. This brings us to the barehanded interaction style, where the users interact with the computer without any device or wires attached. This has been explored and described in [1] to be superior to traditional input devices. This approach was also utilized in [2] to demonstrate human-computer interaction with gestures that are natural and relaxed.

2.3. Ergonomics and Usability

The standard method of using gestures involves users holding their arms up to the display for long periods of time. This has been known to cause a fatigue problem known as the "Gorilla Arm Syndrome" [9, 10, 12] and is considered to be a "known limitation" [11] of gestural interaction. A simple method of overcoming this issue was explored in [2] by allowing users to rest their elbows on a chair armrest. In [5], the author observes the same solution, but was unable to utilize it during certain gestural interactions.

3. Pilot 1

3.1. Approach

A total of 7 (5 male, 2 female) participants were recruited, all volunteers from the Computer Science program at Baylor University. Participants ranged from 21-26 years of age with a median age of 22. Participants were technically skilled and reported to utilizing a personal computer between 28-84 hours per week, with a median of 49 hours per week. None of the subjects have had prior experience with gestural input.

Personal Space interaction starts with a calibration phase where the user is required to select 4 points (top right, top left, bottom left, bottom right) while keeping her elbow rested and anchored to the table. These 4 points create a flat plane which defines her personal space (Figure 3). This flat plane will be mapped to the display device. The anchor point of the elbow has to remain static throughout a chosen calibration.

All gestural input was captured with the Leap Motion. The de facto method currently used in applications developed for the Leap Motion involves the user moving his hands in 3 dimensions while the palm hovers over the device. We created a relative-mapped cursor manipulation program to benchmark the de facto interaction style. For Personal Space, we tilted the device 30 degrees forward. We found this tilting to reduce self-occlusion and improve palm tracking.

3.2. Experimental Design

A series of 7 experiments were designed: 3 to compare gestural navigation between the mouse, the de facto gestural input, and Personal Space, and 2 each to test gestural selection and manipulation between the mouse and Personal Space. The term "navigation" in [12] is

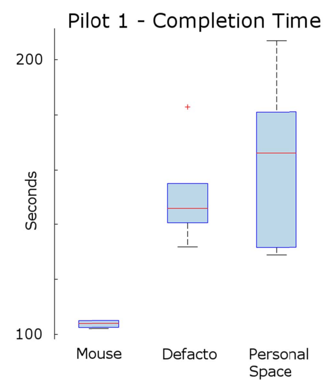

Figure 4. Distribution of completion time for Pilot 1.

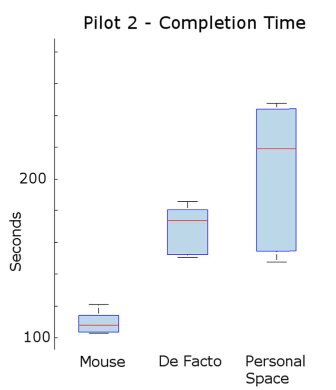

Figure 5. Distribution of completion time for Pilot 2.

broad, and includes 3D navigation, in our experiments we only use 2 dimensions, and will therefore use the term "gestural pointing" as per [3] to be precise.

To assess the performance of the 3 input devices, the total time for each trial was recorded. This is described in [15] as a naive approach compared to throughput, however using Index of Difficulty would be redundant since target size and distance were both held constant.

3.2.1. Gestural Pointing

To assess gestural pointing, a task was designed to benchmark performance and usability of the three interaction styles. The task in the experiment was a game similar to Whac-A-Mole; targets appear at seemingly random locations on the screen, user must hover on the target for one second before they would disappear and another would appear. Each user performs 63 trials per interaction style. The sequence of each trial is the same throughout the experiment, but designed to appear random to the users.

3.2.2. Selection

Selection tasks were done with a left click on the mouse and a finger tap on Personal Space.

3.2.3. Manipulation

Manipulation tasks were done with drag-and-drop on a mouse. With gestural interactions, the users were allowed to use any one of 3 different gestures to select: grasp, grab, and pinch.

3.3. Quantitative Results

Our test subjects required 7-28 minutes of calibration, with a median of 17 minutes.

The distribution for the gestural pointing tasks across all 7 subjects is given in Figure 4. The mean completion times are mouse: 103s, de facto: 150s, and Personal Space: 161s. Our statistical analysis shows a significant difference between the mouse and both methods of gestural input [$F(2, 18) = 16.91$, $p < 0.01$], but none between the de facto method and Personal Space.

The performance measures of selection and manipulation tasks were both significantly slower than the mouse. It will therefore not be given an in-depth analysis, nor will it be explored further in our research.

3.4. Qualitative Results

Subjects were encouraged to alert researchers to any issues during the experiment, particularly subjects mentioning fatigue. Of the 7 subjects, 4 mentioned that the de facto input method was causing fatigue during the experiment. The remaining 3 mentioned it after the task or at the end of the experiment. One mentioned fatigue with Personal Space after the experiment.

Gestural selection received bad reviews, with most subjects reporting pain in their joints. We concluded that the gesture proposed was a bad choice despite being conceptually similar to the actions of a left-click. Gestural manipulation was a difficult task for most users; the cursor tends to move during the selection process and self-occlusion causes the palm to be not accurately detected at certain points of the screen.

4. Pilot 2

The performance of gestures in the first pilot study led us to focus our research on gestural navigation only. The palm-flip gesture used to stop tracking was generally usable, but in the event of a false positive,

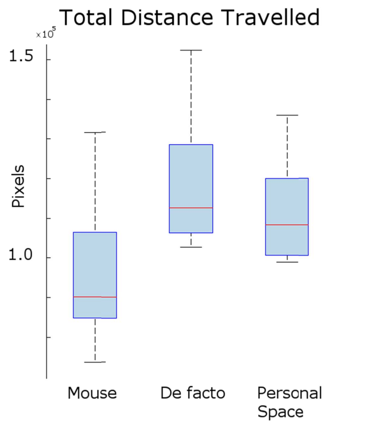

Figure 6. Total distance travelled by the cursor during Pilot 2.

completion time was delayed 5 seconds per false positive. We therefore designed pilot 2, which focused solely on navigation and disabling gestural input completely. Additionally, we captured another metric during this pilot: cursor distance travelled.

4.1. Approach

A total of 5 (4 male, 1 female) participants were recruited, all volunteers from the Computer Science program at Baylor University. Participants ranged from 24-28 years of age with a median age of 24. Participants were technically skilled and reported to utilizing a personal computer between 40-65 hours per week, with a median of 40 hours per week. None of the subjects have had prior experience with gestural input. None of the subjects involved with the first pilot study were recruited for Pilot 2.

4.2. Experimental Design

The same gestural navigation tasks from (3.2.1) were performed by the subjects. Tasks from (3.2.2) and (3.2.3) were not performed in this pilot study.

4.3. Quantitative Results

As in pilot 1, the statistical significance between completion time using the mouse and gestural was significant [$F(2, 12) = 13.09$, $p < 0.01$] while the de facto gestural input method was not statistically different to Personal Space (Figure 5). The means for completion times are mouse: 109s, de facto: 168s, Personal Space 203s. In terms of total distance travelled by the cursor, as shown in Figure 6, we surprisingly found no statistically significant difference between all 3 input devices. The means for distance travelled (x10^3 pixels) are mouse: 96, de facto: 119 and Personal Space: 111.

4.4. Qualitative Results

We observed that four of the subjects started the de facto experiment with their elbows in a resting position and expected to be able to keep it rested throughout the experiment. Three subjects mentioned fatigue during the de facto method within 90 seconds and one subject asked to switch arms halfway through (this was allowed). Conversely, no subject mentioned fatigue while using Personal Space. However, one did mention discomfort in fingers and palm after the experiment.

5. Discussion and Future Works

The main contribution of our research so far is an interaction style that very significantly reduces the Gorilla Arm Syndrome, without sacrificing performance. This is despite the non-linear mapping used to map the user's palm position and the cursor. While this method was done with a free-hands technique, we propose that this same technique can be used for any other gestural input device, including data gloves.

The next step of our research will be to implement the users' space in a curvilinear model instead of a flat plane. We believe this will map the natural angle of the arm much better based on Figures 3 and 4.

Our next experiments will include an index of difficulty. This will include truly random target positions, and different target sizes. Performance will be calculated in throughput and evaluation will also be done with the ISO 9241-400:2007 specification.

The statistical insignificance in travel distance leads us to believe there is a comparatively high accuracy between the Personal Space approach and the mouse. We intend to explore this hypothesis in the near future.

6. Conclusion

In this paper, we have introduced Personal Space, an interaction method for gestural pointing which allows users to define their own space captured through a calibration stage. This space uses a non-linear mapping between palm position and cursor position. This method has shown to be equal in performance to the de facto gestural method, but far superior in usability.

7. References

[1] Von Hardenberg, Christian, and François Bérard. "Bare-hand human-computer interaction." Proceedings of the 2001 workshop on Perceptive user interfaces. ACM, 2001

[2] Freeman, Dustin, Ramadevi Vennelakanti, and Sriganesh Madhvanath. "Freehand pose-based Gestural Interaction: Studies and implications for interface design." Intelligent Human Computer Interaction (IHCI), 2012 4th International Conference on. IEEE, 2012.

[3] Vogel, Daniel, and Ravin Balakrishnan. "Distant freehand pointing and clicking on very large, high resolution displays." Proceedings of the 18th annual ACM symposium on User interface software and technology. ACM, 2005.

[4] Bolt, Richard A. "Put-that-there": Voice and gesture at the graphics interface. Vol. 14. No. 3. ACM, 1980.

[5] Segen, Jakub, and Senthil Kumar. "Look ma, no mouse!." Communications of the ACM 43.7 (2000): 102-109.

[6] Lai, Kam, Janusz Konrad, and Prakash Ishwar. "A gesture-driven computer interface using Kinect." Image Analysis and Interpretation (SSIAI), 2012 IEEE Southwest Symposium on. IEEE, 2012.

[7] Biswas, K. K., and Saurav Kumar Basu. "Gesture Recognition using Microsoft Kinect®." Automation, Robotics and Applications (ICARA), 2011 5th International Conference on. IEEE, 2011.

[8] Triesch, Jochen, and Christoph Von Der Malsburg. "Robotic gesture recognition by cue combination." Informatik'98. Springer Berlin Heidelberg, 1998. 223-232.

[9] Yoo, Juwan, Seungyup Lee, and Chieteuk Ahn. "Air Hook: Data preloading user interface." ICT Convergence (ICTC), 2012 International Conference on. IEEE, 2012.

[10] Carmody, T. "Why 'Gorilla Arm Syndrome' Rules Out Multitouch Notebook Displays." (2011). [online] http://www.wired.com/gadgetlab/2010/10/gorilla-arm-multitouch/

[11] Teixeira, Vítor. Improving elderly access to audiovisual and social media, using a multimodal human-computer interface. Diss. Faculdade de Engenharia, Universidade do Porto, 2011.

[12] Wachs, Juan Pablo, et al. "Vision-based hand-gesture applications." Communications of the ACM 54.2 (2011): 60-71.

[13] Wang, Robert Y., and Jovan Popović. "Real-time hand-tracking with a color glove." ACM Transactions on Graphics (TOG). Vol. 28. No. 3. ACM, 2009.

[14] Jacob, Robert JK, et al. "Reality-based interaction: a framework for post-WIMP interfaces." Proceedings of the SIGCHI conference on Human factors in computing systems. ACM, 2008.

[15] Zhai, Shumin. "Characterizing computer input with Fitts' law parameters—the information and non-information aspects of pointing." International Journal of Human-Computer Studies 61.6 (2004): 791-809.

[16] G.M. Poor, Brianna J. Tomlinson, Darren Guinness, Samuel D. Jaffee, Laura M. Leventhal, Guy Zimmerman, Dale S. Klopfer. "Tangible or Gestural: Comparing Tangible vs. Kinect™ Interactions with an Object Manipulation Task." 7th International Conference on Tangible, Embedded and Embodied Interaction, 2013.