Handymenu: Integrating Menu Selection into a Multifunction Smartphone-based VR Controller

Nicholas G. Lipari* Christoph W. Borst†

University of Louisiana at Lafayette

ABSTRACT

We integrated touch menus into a cohesive smartphone-based VR controller. Smartphone touch surfaces offer new interaction styles and also aid VR interaction when tracking is absent or imprecise or when users have limited arm mobility or fatigue. In Handymenu, a touch surface is split into two areas: one for menu interaction and the other for spatial interactions such as VR object selection, manipulation, navigation, or parameter adjustment. Users in our studies transitioned between the two areas and performed nested, repeated selections. A formal experiment included VR object selection (ray and touch), menu selection (ray and touch), menu layout (pie and grid), as well as touch and visual feedback sizes in some cases (two levels each).

Keywords: Touch, Menus, Virtual Reality, 3DTV, Smartphone

Index Terms: I.3.6 [Computer Graphics]: Methodology and Techniques—Interaction techniques; H.5.1 [Information Interfaces and Presentation]: Multimedia Information Systems—Artificial, augmented, and virtual realities

1 INTRODUCTION

We study VR interaction using smartphone-based input, which may be promising when tracking is limited or the user has fatigued or impaired motion. Recent studies also suggest benefits of touch over standard ray selection [1] [2] [3] and present new interaction styles. Gebhardt et al. [1] combined smartphone menus and ray object selection via separate hands or devices. Our touch-only Handymenu uses smartphone touch input for menu access in a trigger area, and other spatial interactions occur in the remaining (other) touch area. Menu visuals appear on the main display (in our evaluation, a 3D TV). Transitions between the touch areas and efficient use of the touch surface pose interesting questions.

We consider how to integrate touch menus into prior VR touch interfaces. For example, Bergé et al [4] created smartphone-based VR navigation using 2D input and display. Debarba et al. [5] combined coarse ray pointing with touch input for two levels of precision. Prachyabrued and Borst [2] created Handymap touch-based map selection that outperformed ray for certain cluttered environments [3]. Handymap worked best when visual feedback in the 3D scene revealed touch position, using the smartphone only as an input surface, avoiding focus shifts. Techniques avoiding smartphone visuals also integrate more readily into VR displays blocking the real-world view (e.g., HMDs).

We conducted both objective and subjective evaluations. The VR environment was sparse and simple for target selection, as our focus was on menu aspects, and touch target selection is addressed elsewhere (e.g., [2] [3] [5]). Our main questions were:

* e-mail: ngl3747@cacs.louisiana.edu
† e-mail: cwborst@gmail.com

IEEE Symposium on 3D User Interfaces 2015
23 - 24 March, Arles, France
978-1-4673-6886-5/15/$31.00 ©2015 IEEE

Q1: What is the basic performance and feasibility of the menu? Mainly, how does it compare to standard ray menus, and can users consistently transition between interaction areas? Gebhardt et al. [1] found that list menus presented on a smartphone could be faster than ray-based pie menus. Olwal and Feiner [6] used a touch display for interaction with a larger main display (zooming and selection of small targets) and showed overall higher user preference over direct selections on the main display. While the task had two components, both were performed in the same space.

Q2: How do different size and layout conditions affect menu interactions? Smaller touch menus leave more area for other operations, but may lead to menu problems. Hansen and Hald [7] determined optimal movement ranges for handheld menus, considering only homogeneous tasks. Regarding layout, we consider a grid layout that can fill a rectangular area with equally-size menu items, in comparison to a pie layout that cannot do this.

Q3: Given an interface that already relies on touch for operations like VR object selection or navigation, should menu selections also use touch or switch to ray selection? Gebhardt et al. [1] include a different type of switch between hands or devices, wherein the touch component is used for menus only.

2 MENU INTEGRATION WITH EXAMPLE APPLICATION

Handymenu could be integrated with various VR touch interfaces by designating a menu trigger area. Our initial purpose was to combine in-scene object selection, navigation, and menus on a touch controller for browsing objects above a terrain (representing real-world sensor data). The default behavior of the main touch area was map-like object selection. Other behaviors, including navigation, were accessed by menu selection followed by spatial input. For example, users moved through the scene by selecting "pan" and then sliding the thumb in the main touch area to grab and slide the terrain along its principal plane. 2D orbiting about the current view center was similarly done by a menu selection followed by 2D adjustment (azimuth, elevation). Other operations included scale (2D for uniform and vertical effects) and per-object data plot triggering followed by plot operations. Following prior work [2] [3], menus were shown only on the main display to avoid focus shifts. Our design used at most 6 items per menu.

3 METHODS

We varied the proportion of touch areas, menu layouts, selection type combinations, and a visual feedback size. Subjects performed three selections in sequence: a target sphere selection in an upper touch area and two menu items (two-level menu selection) from a lower area. Targets, touch position indicators, and menus were viewed on the main display and not on the controller. We recorded selection timings, error counts, and touches of incorrect selection areas, along with user ratings.

3.1 Apparatus

Subjects wore Nvidia 3D Vision glasses with tracking markers and held an iPod Touch with tracking markers for interactions. An OptiTrack V120 Trio performed tracking. The main display was a Mitsubishi 65-inch DLP TV (Figure 1). The touch surface measured 4.9 cm by 7.4 cm. Subjects stood 150 cm from the TV. Minimal visuals were shown on the iPod (Figure 2c).

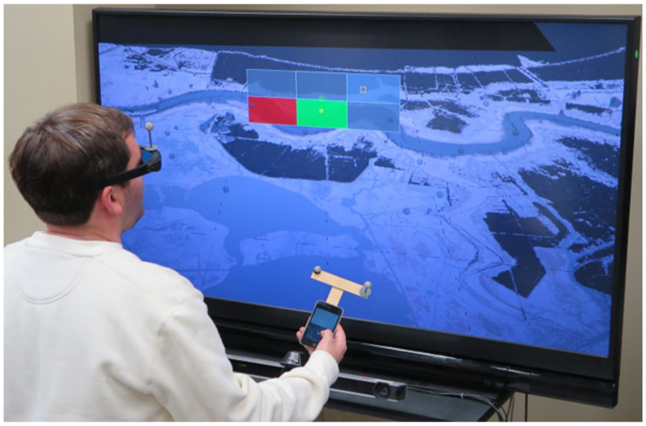

Figure 1: Experiment apparatus. A 3DTV presented visuals to subjects wearing active stereo glasses and holding an iPod Touch. 3 x 2 grid menu on TV enlarged for figure clarity.

3.2 Pilot Studies

We initially conducted three pilot studies with seven total users, presenting several menu variations (e.g., menu placement on TV, touch device, touch menu size) to identify interesting factors. Contextual in-scene menus were chosen over fixed-position menus to avoid disorienting aim shift from object selection. A 4th-generation iPod Touch was chosen over a larger 5th-generation version for better average hand fit (some subjects disliked large thumb interaction motions). Five touch menu sizes, with heights from 0.8 cm to 3.7 cm, were tested for touchdown errors (wrong area touch). We settled on 1.6 cm and 3.7 cm as reasonable limits and as conditions for formally testing tradeoffs. We found that requiring users to lift the thumb to transition between touch areas was better than switching behaviors whenever the border was crossed, as this could occur accidentally. Other results included tuning visuals to address possible color blindness problems and to give clear indicators of touch position or ray intersection, including a small circle indicator on menus. We confirmed that a ray should only be visible during ray selection phases.

3.3 Design

The experiment conditions are listed in Table 1.

Touch menu size: We varied touch selection area between large and small sizes (Figure 2): half the handheld touch area (more near a square, better fitting a pie menu) and rectangular 3:1 (matching a grid menu). The smaller area resulted in uniformly scaled touch movements for pie, as suggested by Figure 2b. In all cases, if the thumb moved out of the visualized menu but stayed in the menu area, the closest item remained active and selectable.

Menu layout and size: We included 6-slice pie and 3x2 grid menus. Their relative visual sizes on the TV matched the ratio of touch menu sizes in Figure 2(a). The ratio between pie radius and single grid item width was 9:8. Visual menus were optimized for ray selection, except in a condition checking a confounding effect of visual size. A prior study of ray-selected pie menus [8] reported angular menu item size subjectively tuned to 4.5° and good performance for 4.0° items. At the 150 cm view distance, a 4.5° projected width is 11.8 cm at screen center. We chose this size for pie radius, and the grid layout was sized by the above ratio. The special case (extra condition) had a visual pie menu scaled down like the smaller touch area. Visual sizes were kept constant by scaling menu geometry to counteract perspective foreshortening. This improves ray selection performance consistency [8].

Target sphere selection: For changing menu area size, we translated the target sphere touch mapping to keep equal distance between menu center and target sphere group center (Figure 2a,b). This was to avoid a possible confounder related to the distance.

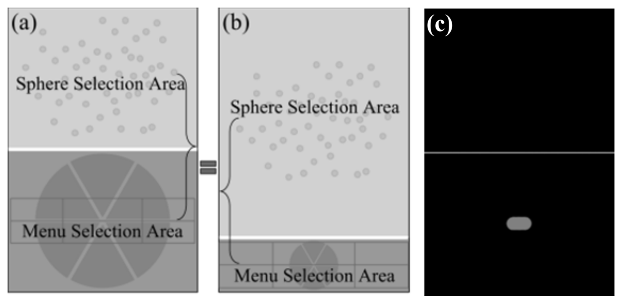

Figure 2: *A and B*: Small and large conditions with relative menu sizes. *C*: Minimal iPod visuals (menu area center and boundary).

3.4 Task, Subjects, and Procedure

There were 20 voluntary experiment subjects (18 male) from students and alumni of the author's university. The median age was 26. Ages ranged from 20 to 36. All subjects used their dominant hand for the experiment. 19 subjects were right-handed.

Instructions appeared on the TV. We asked subjects to look only at the main display and select "quickly, but without errors."

Thirty spherical targets were arranged randomly above a visualized terrain. A sphere changed color from gray to saturated

Table 1: Experiment conditions. An acronym formed from the components identifies each condition.

Condition	Sphere Selection	Menu Selection	Menu Layout	Touch Menu Size	Visual Feedback Size	Comments
RRG	Ray	Ray	Grid	N/A	Large	Common VR ray technique gives a standard performance reference.
RRP	Ray	Ray	Pie	N/A	Large	
TRG	Touch	Ray	Grid	N/A	Large	Mixing ray menus with touch sphere (target) selection to consider feasibility or problems.
TRP	Touch	Ray	Pie	N/A	Large	
TTG-Ltch	Touch	Touch	Grid	Large	Large	Touch-only grid menus in large and small areas.
TTG-Stch	Touch	Touch	Grid	Small	Large	
TTP-Ltch-Lvis	Touch	Touch	Pie	Large	Large	Touch-only pie menu in large and small areas.
TTP-Stch-Lvis	Touch	Touch	Pie	Small	Large	
TTP-Stch-Svis	Touch	Touch	Pie	Small	Small	Extra case checks possible visual size confounder.

green, to prompt selection. Subjects selected spheres with the thumb in the upper area (touch-refine-release) or with ray, using touch as a trigger (tap anywhere). For either method, the closest sphere was selected. A menu appeared just in front of the sphere. Two randomized menu items were colored green and red. Subjects selected the green item. The colors swapped, and subjects selected the second item. The green item was also indicated by an asterisk in both cases. Correct selections were enforced (retry until correct); a tone indicated correctness.

Subjects performed 10 training and 30 testing trials per condition, with order randomized per subject. Per condition, every ordered pair of menu items appeared once (6•5=30, i.e., all possible non-repeating pairs from 6 menu items). After the trials, subjects reviewed each condition, specified one of the categories: Best, Indifferent, and Worst, and provided their reasoning.

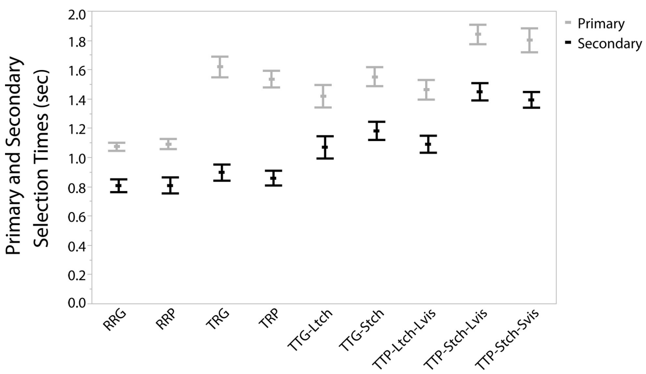

Figure 3: Primary and secondary selection times (mean +/- 1SE).

3.5 Results and Discussion

Figure 3 summarizes menu selection times. Secondary menu items are less dependent on factors such as initial area targeting cost, shifts in interaction style, or non-menu scene aspects. Target sphere selection is not detailed because it was simplified (Section 1), but we note that mean sphere selection time was 1.78 sec (SD=0.32) for ray and 2.02 seconds (SD=0.45) for touch. Within touch, it was 1.92 sec when menu area was large (SD=0.34), 2.00 sec (SD=0.35) when small, and 2.18 (SD=0.62) in mixed cases.

Q1: Regarding ray vs. touch selection of menus, subjects selected both menu levels faster with ray-only techniques than touch-only. On average, the ray-selection conditions RRP and RRG were 32.98% faster (*Z=7.71, p<0.001, Wilcoxon Signed-Rank*) for primary selection and 34.7% faster (*Z=6.91, p<0.001*) for secondary selection. The fastest touch-only condition was TTG-Ltch. Compared to TTG-Ltch, the mean primary selection time for RRG was 24.4% faster (*Z=3.48, p<0.001*), and secondary selection time was 24.5% faster (*Z=2.69, p=0.007*).

To check the ability of users to transition between interaction areas, we recorded the total number of times each area was missed during the 30 trials per user and condition for the 5 touch-only conditions, including repeated misses (Figure 4). Median counts were low for both sphere and menu areas when touch menu area was large (medians between 0 and 2, i.e., at most 6.7% of trials). Overall median for menu area was 8. Overall median for sphere area misses was 1 (3.3%). Users can maintain area separation well with good area size choice (discussed further for Q2).

Q2: For touch selection of menus, the grid layout had faster primary (*Z=-2.84, p=0.005)* and secondary selections (*Z=-2.72, p=0.007)* than pie. This can be mainly attributed to small cases, where a grid layout better uses the touch area (TTG-Stch). Grid performance depends less on touch area size. Trigger area misses are illustrated in Figure 4. Subjects had more difficulty triggering the small menu area than the large one (*Grid: Z=2.01, p=0.045; Pie: 2.47. p=0.014).* Pie layout also had more menu area misses than grid (*Z=-2.12, p=0.034*). Layout effect may relate to menu visual feedback on the main display. Grid menus were shorter than pie menus, possibly causing subjects to aim lower to trigger, even though touching anywhere below the boundary (Figure 2c) triggered the menu. Subjects had more difficulty starting sphere selection when menu area was large (*Z=3.25, p<0.001),* with 144% more sphere area misses. Optimal menu size may be a bit less than half the touch display's height.

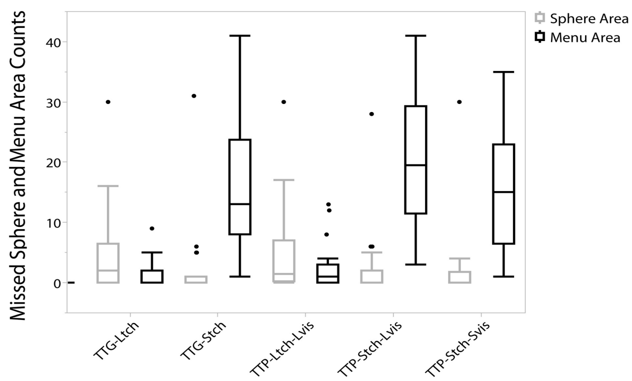

Figure 4: Box and whiskers plot of missed sphere and menu area counts (number of times subjects touch the incorrect selection area). Outliers are shown as solid circles. Conditions with ray-based selections are excluded (entire surface triggered equally).

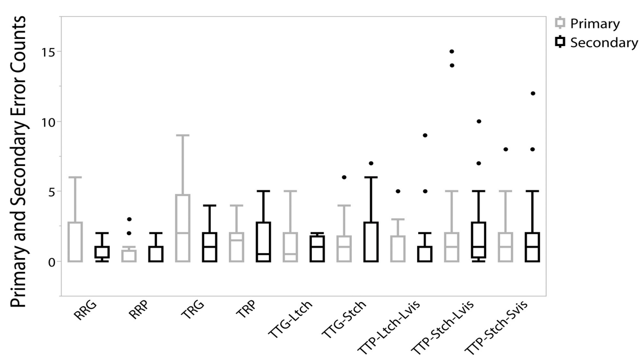

Figure 5: Error counts: The number of times an incorrect menu item was selected (box and whiskers plot with outliers as small circles).

Incorrect menu selections (Figure 5) were analyzed per level (primary; secondary). Plot inspection suggests the best ray case was RRP and the best touch cases were large (TTP-Ltch-Lvis and TTG-Ltch). Comparing TTP-Ltch-Lvis to TTG-Ltch, we did not detect significant effect of layout on selection errors (*Z=-0.889, p=0.379; Z=-0.895, p=0.371*). Comparing these to ray condition RRP, we also did not detect any effect of selection technique.

RRG and TRG results suggest large dispersion for primary menu errors compared to secondary. The asymmetry of grid style menus may cause difficulty for some users when initially selecting menu items with ray. This improves for secondary selections requiring mostly small lateral movement.

Q3: When comparing the mixed mode conditions TRP and TRG to touch-only and ray-only, touch-only was nearly equal for primary menu selections (2.5% slower, no detected effect), and 29.02% slower (*Z=6.07, p<0.001*) for secondary, and ray-only was faster on average (primary: 31.4% *Z=-7.28, p<0.001*; secondary: 7.97%, no detected effect). The primary and secondary selection times within the ray-only and touch-only conditions appear to differ by a consistent offset. A clear increase appears in the differences within mixed conditions TRG and TRP. Since the larger difference occurs regardless of layout, it is likely indicative of the extra shift needed to orient the ray-pointer after touch sphere selection. Pairwise Wilcoxon Signed-Rank tests of the differences were conducted with Bonferroni corrections. Of all 36 pairwise comparisons of 9 conditions, the mixed conditions had significant effects against all single-mode conditions (*p<0.05*).

Touch interactions for pie layout nearly filled the touch area of large touch, and grid layout exactly matched that of small touch (as illustrated in Figure 2a-b, respectively). For further analysis, the conditions were grouped into G1: ray menu selection conditions (the first four in Table 1), G2: touch menu selection conditions where touch area fits the menu layout well (the next three), and G3: touch menu selection conditions where the small touch size caused menu interaction to be compressed (last two).

Based on Bonferroni-corrected pairwise Wilcoxon Signed-Rank tests, selection times (*primary*; *secondary*) showed a significant effect between consecutive pairs of the three groups. Ray-based menu selections G1 were faster than G2 and G3 (*Z=3.04, p=0.007; Z=5.75, p<0.001*). Mixed conditions TRG and TRP were comparable to G2 for primary selection (6.8% slower) but moderately faster (26.9%) for secondary selections (*Z=-4.29, p<0.001*). For G2, menus better filled the touch area and selections were faster than G3's small touch areas with unused space (*Z=4.70. p<0.001; Z=4.93, p<0.001*).

Subjects preferred ray selection to touch selection (Figure 6). Remarks from six subjects suggested ray pointing was more intuitive. Small touch area conditions received the Worst ranking from subjects 41.7% of the time and Best 15% of the time. No other condition was placed in Worst more than 20% of the time. In small touch area rankings, grid layout was preferred to pie layout, following from the better use of available menu area by a grid layout. The preference matches the menu selection timings above. Three subjects did not realize the touch menu width in TTG-Stch matched that in TTG-Ltch. The smaller menu area allows a larger area for virtual object selection or other tasks.

Although the small visual menu (TTP-Stch-Svis) was regarded as the worst condition, menu selection times and error counts were generally close to that of the large visual size (TTP-Stch-Lvis. The possibly confounding effect of visual size appears to have minimal influence, if any, on touch menu timings.

4 Conclusion

Subjects were overall able to maintain both touch areas as separate targets, starting in the correct location most of the time, despite being novices. Touch menu selections were moderately slower than ray-based. Touch selection of menus did improve with a large selection area or a menu layout that best filled the area. Size tradeoffs suggest a slightly smaller menu area than our large case may be optimal. Smaller menus may still be desirable in some cases, depending on techniques in the upper area.

To consider modes of integration of a menu into an existing touch interface, we compared touch-only conditions to mixed ray-touch conditions. Mixed conditions performed similarly to touch-only conditions for primary selection, suggesting touch-only interaction is appropriate for single-level menu performance. For multi-level menus, selection times show an advantage of ray.

Other smartphone menu approaches include using embedded rotation sensors, which we did not do here. Das and Borst [8] studied a relative rotation-based menu. Its speed appears to be in between touch and ray speeds, but this may change with integration into a multifunction interface. Touch-only interaction may provide a more seamless experience. The addition of a physical boundary indicator (suggested by a reviewer) may provide useful touch feedback. Larger touch devices may match two-handed interaction, or use of only a sub-region. Future work can also consider if such touch interfaces benefit impaired users.

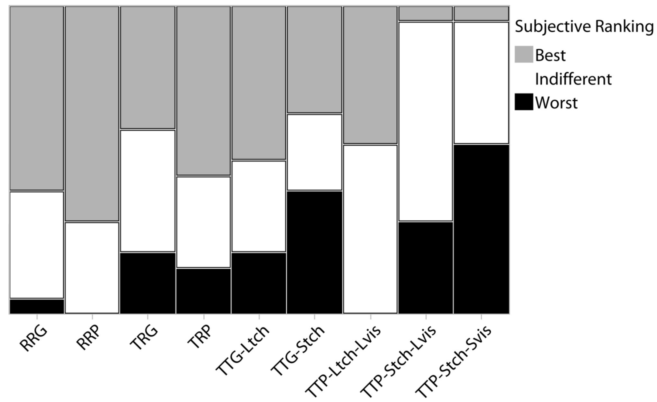

Figure 6: Mosaic of Subjective Ranking for Conditions. Rankings from the top to bottom are Best, Indifferent, and Worst.

Acknowledgments

This research was funded by the Center for Visual and Decision Informatics (CVDI), an Industry/University Cooperative Research Center of the National Science Foundation, members from an Industry Advisory Board, and University matching funds. Information about CVDI can be found at http://www.nsfcvdi.org/. We thank Dr. Mores Prachyabrued for earlier Handymenu work, and thank Dr. Raju Gottumukkala and Sivarama Krishna Venna.

References

[1] S. Gebhardt, S. Pick, T. Oster, B. Hentschel and T. Kuhlen, "An evaluation of a smart-phone-based menu system for immersive virtual environments," in *IEEE 3DUI*, 2014.

[2] M. Prachyabrued, D. Ducrest and C. W. Borst, "Handymap: A Selection Interface for Cluttered VR Environments Using a Tracked Hand-held Touch Device," in *ISVC*, 2011.

[3] P. V. Vemavarapu and C. W. Borst, "Evaluation of a Handheld Touch Device as an Alternative to Standard Ray-based Selection in a Geosciences Visualization Environment," in *Workshop on Off-the-Shelf Virtual Reality*, 2013.

[4] L.-P. Bergé, G. Perelman, M. Raynal, C. Sanza, M. Serrano, M. Houry-Panchetti, R. Cabanac and E. Dubois, "Smartphone-Based 3D Navigation Technique for Use in a Museum Exhibit," in *ACHI*, 2014.

[5] H. Debarba, L. Nedel and A. Maciel, "LOP-cursor: Fast and precise interaction with tiled displays using one hand and levels of precision," in *IEEE 3DUI*, 2012.

[6] A. Olwal and S. Feiner, "Spatially Aware Handhelds for High-Precision Tangible Interaction with Large Displays," in *Tangible and Embedded Interaction*, 2009.

[7] N. T. Hansen and K. Hald, "System Control, Navigation & Selection Using Off-the-Shelf Hardware for a Classroom Immersive Virtual Environment (Master's Thesis)," Aalborg Universitet, Aalborg, 2014.

[8] K. Das and C. W. Borst, "VR Menus: Investigation of Distance, Size, Auto-scale, and Ray Casting vs. Pointer-attached-to-menu," in *ISVC*, 2010.