Insights on Interactive Tabletops: A Survey of Researchers and Developers

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ABSTRACT
Recently, interest in tabletop computing has surged, both within the research community and within the commercial sector. However, given the early stage of interactive tabletop adoption and current low availability, it is difficult to find end users with extended experience in using such devices. We conducted a survey of 58 tabletop researchers and developers, the only available population with longer-term tabletop use experience, to find out how they use their devices, what they use them for, and what features they consider important for novice, single-user, and collaborative scenarios. While not without inherent biases, their answers suggest important directions for further research in designing and evaluating interactive tabletop systems, including identification of obstacles to mainstream adoption, and input and ergonomic challenges.

Keywords
Surface computing, interactive tabletops, digital desks.

INTRODUCTION

HCI researchers have been experimenting with horizontal computing form-factors for many years; Wellner's DigitalDesk [12] explored this direction in the early 1990s. More recently, hardware has debuted that can reliably sense rich input from multiple simultaneous contacts, such as DiamondTouch [2], FTIR [5], and PlayAnywhere [14]. Benefits ascribed to horizontal interactive surfaces include ease of use and intuitiveness due to multi-touch direct manipulation, quick learning time for novice users, and support for collaborative work.

However, despite the popularity of interactive tabletops in the research community, and the media excitement surrounding the announcement of commercial tabletop systems (*e.g.,* the Microsoft Surface and the Philips Entertaible), there is little data available on their use in practice (as opposed to brief use experiences during lab studies). Wigdor *et al.* [13] and Mazalek *et al.* [7] each provide case-study data on a single user's longer term experience with a tabletop technology, and Morris *et al*. [9] report on eight office workers' use of interactive desks. Examining people who regularly use interactive tabletops could address questions such as:

- How extensively are tabletop systems being used, and what are they used for?
- What features are most important for collaborative use? Individual use? For novice users?
- What features make tabletops better than standard computer interfaces?
- What features are still needed, but lacking?
- What features define an "interactive tabletop"?

We sought to answer these questions by surveying people who interact with tabletop systems on a regular basis. In December 2007, we conducted a web-based survey consisting of 33 multiple-choice and free-response questions. Participants were recruited via e-mail sent to researchers who publish tabletop research in venues such as CHI, CSCW, and IEEE TableTop, as well as to designers and developers on tabletop product teams at companies such as Microsoft, Mitsubishi Electric, Perceptive Pixel, Philips, SMART Technologies, and Sony.

We are aware that the chosen population does not represent the target end users of tabletop technology. However, given the early stage of interactive tabletop adoption and current low availability, there are few, if any, actual end users, and the only population with longer-term tabletop use experience are tabletop researchers, developers, and designers. Surveying tabletop innovators has some limitations, such as the risk of biases toward excessive optimism regarding the potential of tabletops, and it is important to bear these limitations in mind when interpreting our results. Once there is a significant population of end-users who interact with tabletop technology on a regular basis (and thus would not be biased by novelty effects or overly focused on particular, individual applications), conducting an end-user survey would offer an interesting complement to our current findings. We hope to be able to conduct such a survey soon.

58 respondents completed the survey (12% female). 46% were from universities and 44% were from industry; the remaining 10% had other affiliations such as "between-positions" or "self-employed." Most respondents reported having between two and five years of experience using interactive tabletops, with 7% reporting more than ten years of tabletop experience and 14% reporting one year

or less. Respondents used a variety of tabletop hardware: most used well-known systems such as MERL's DiamondTouch or Microsoft's Surface, while 33% reported using custom, self-made technologies.

Our complete, anonymized data set can be downloaded from http://research.microsoft.com/~benko/projects/tabletop_survey/. In the remainder of this paper, we present data and analysis regarding use patterns, valued features, and impediments to adoption. We conclude by identifying key directions for further research suggested by our findings.

USE PATTERNS

We were surprised how infrequently tabletop developers and researchers used tabletop computers. Only 27% of respondents reported using interactive tabletops several times a day, while 33% reported using tabletops at most once per month. Respondents reported typical tabletop use sessions of between fifteen minutes and one hour.

Given our population, it was no surprise to find out that the most common tasks were the development of novel interactive tabletop applications and usability studies of tabletop software (78% and 56% of respondents, respectively). 36% of respondents reported using their tabletops for viewing entertainment media such as videos or photos, and 31% reported using them for collaborative activities such as brainstorming. 17% used their tables for visualization applications. Only 5% reported using their tabletop systems to accomplish "productivity" tasks (*e.g.*, word processing, spreadsheets, e-mail, Internet activities, etc.), and only a single respondent reported using an interactive tabletop as an all-purpose, primary computing device.

In addition to reporting their own use patterns, respondents gave Likert-scale ratings (1 = unsuitable, 5 = extremely suitable) to task categories to indicate how appropriate they felt such tasks were for the tabletop form factor. These ratings followed the same trends as self-reported use patterns, with entertainment (μ=4.5), visualization (μ=4.4), and collaborative activities (μ=4.3) rated as extremely suitable, and presentations (μ=3.1) and productivity applications (μ=2.4) judged unsuitable.

IMPORTANCE OF TABLETOP FEATURES

To understand the importance of different features of tabletops, we asked respondents to rank a list of features commonly associated with interactive tabletops (see labels in Figure 1) in three likely scenarios: (1) collaborative use, (2) long-term, individual (single-user) use, and (3) attracting and appealing to novice users. For each scenario respondents were asked to rank the top five most-desirable features. Figure 1 shows, for each scenario, how many times each feature from the set was given a top-five ranking, and Figure 2 summarizes the features most-frequently ranked among the top five most valuable for each of these three scenarios. Note that for these questions, we asked participants to disregard the fact that some features might not be available on the systems they owned, but to instead imagine the features that would be desirable in an "ideal" tabletop system.

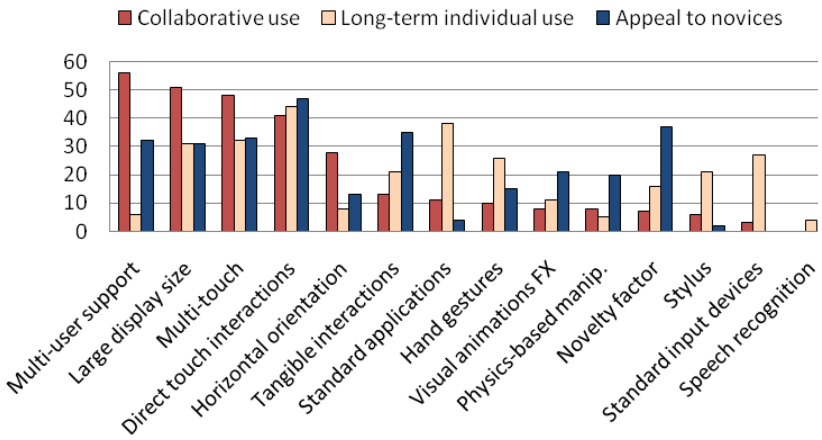

Figure 1. Side-by-side comparison of votes for top-five rankings for each of the three usage scenarios.

Collaborative use	Votes	Long-term individual use	Votes	Appeal to novices	Votes
Multi-user support	57	Direct touch	44	Direct touch	48
Large display	53	Standard applications	39	Novelty factor	38
Multi-touch	49	Multi-touch	33	Tangible interactions	36
Direct touch	42	Large display	31	Multi-touch	34
Horizontal orientation	28	Standard input devices	28	Multi-user support	32

Figure 2. Aggregated top-five rankings for each of the three usage scenarios.

We also collected free-form responses to the question: "What single feature of interactive tabletops do you miss most when using a standard desktop computer?" Responses were independently classified by three of the authors, who then reconciled these classifications to reach agreement on categories of similar responses (Figure 3).

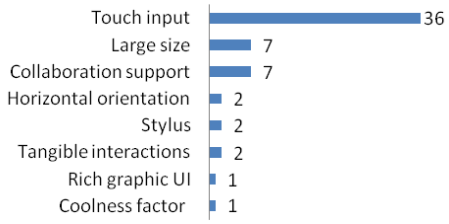

Figure 3. Category counts for free-form responses on most-missed tabletop features when using desktop computers.

Looking at the responses, direct touch and multi-touch input appear to be the two most-agreed-upon high-value features, both landing in the top five for all three of the sample scenarios (Figure 2). The free-form responses shown in

Figure 3 echoed the trends of the feature-ranking, with touch input the overwhelmingly most popular response.

Having a large display size was also considered a high-value feature – large displays were considered important for collaborative scenarios, but were also desired for solo use; however, large display size did not rank in the top five for novice appeal. Large display size was the second most popular answer to the free-response question. When asked about the diagonal size of their current tabletop, respondents reported sizes ranged from 5" to 108" with a mean size of 42" (σ=20").

One of the most obvious features of tabletops is their orientation; however, it was ranked in the top five only for collaborative work. Horizontal orientation *per se* was rarely cited in response to the free-form question, although collaboration support was one of the most popular free-form answers. Tangible interactions made the top five only for novices, while respondents also felt that the novelty of interactive tabletops was an important part of novice appeal. Multi-user support was also considered important for generating excitement among novices about tabletop computing, but was not as highly ranked for the other two scenarios.

FEATURES NEEDING IMPROVEMENT

We gathered information about the challenges associated with using interactive tabletops through several questions, including "What single feature of standard desktop computers do you miss most when using an interactive tabletop?" (Figure 4 shows responses categorized, once again, by a review process of three of the authors). We also asked about the biggest frustrations faced when using tabletops displays, and solicited free-form explanations regarding whether they would consider using an interactive tabletop as their primary computer (24% answered "yes", 33% "maybe", and 41% "no).

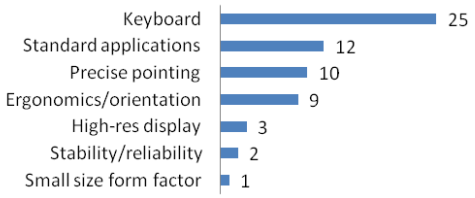

Figure 4. Category counts for free-form responses on most-missed desktop features when using interactive tabletops.

Text Entry Issues

The keyboard was the desktop feature most-missed when using an interactive tabletop (Figure 4). Comments on respondents' greatest frustrations highlighted the difficulty of text entry including: "lack of decent keyboards", "virtual ones don't work well", "physical ones may occlude" and "typing, soft keyboard works poorly, no feedback." Improved text entry method was also cited by four respondents as the main improvement needed in order to consider using a tabletop as a primary computer (out of 19 who responded "maybe").

Support for standard applications (email, the Web, etc.) on tabletops was the second most-missed feature, closely followed by precise pointing (Figure 4). It is not surprising that the difficulty of text input without a keyboard and the lack of precise pointing make it very challenging to adapt standard applications designed for mouse and keyboard to tabletop displays. What is surprising is that most of the tabletop research so far has featured interactive tabletops without considering the possibility of them being used with a standard keyboard and mouse as well as touch. Judging from the responses in our survey, we believe that a closer look should be taken at integrating standard input devices and multi-touch interactions into a rich input palette. In fact, we suggest that the abilities of some tabletops to sense objects on the surface should be used to further enhance the existing functionality of the standard mouse and keyboard, for example, by providing context-sensitive modes, additional tracking, etc.

Ergonomic Issues with Horizontal Orientation

Another theme was the poor ergonomics of using a horizontal form-factor. For example, explanations of why respondents would not use a tabletop computer as their primary device included comments such as: "I would need a vertical display for a primary computer, as horizontal causes a fair amount of neck strain," "It is not ergonomic – neck muscle strain occurs after looking down (even just a few degrees) after about an hour of computer use," and "Long-term use of a horizontal tabletop … is not good for your back." Figure 4 also shows that ergonomics was highlighted as an aspect of desktop PC use that people missed when using tabletop computers.

The desire to adjust the angle of the tabletop surface was mentioned by seven respondents. Their remarks included: "I would like it to … offer me the possibility to choose the angle and the screen surface on which I want to work" and "Must have angled surface, or even better adjustable surface angle." We believe that allowing angle adjustment might help alleviate some of the ergonomic issues mentioned above. One respondent suggested that adjusting the tabletop angle might also ease transitioning between single-person and collaborative use. The respondent wanted a tabletop that "is not purely horizontal and that can be easily changed to a horizontal table for collaborative tasks."

DISCUSSION

Our survey population consisted of tabletop researchers and developers, a group that one would expect to use interactive tabletops frequently; however, only 27% reported using tabletops on a daily basis. We speculate that the reported lack of standard applications for performing productivity tasks and the lack of support for standard input devices resulted in low overall use beyond development and evaluation tasks. Respondents' relatively low use of their interactive tabletop systems may also indicate that tabletop systems' true role is as a special-purpose device, to be used only during brief intervals for specialized tasks, such as during collaborative meetings.

Identification of appropriate applications for interactive tabletops was identified as a research challenge by Scott *et al*. in 2003 [10]. Our findings indicate that this challenge remains unresolved, with little agreement among respondents on the specific tasks accomplished using their tables, beyond the general notion that

tabletops are more suited for collaborative activities than for standard office productivity applications.

Responses to questions about features in need of improvement suggest that several shortcomings of interactive tabletop technology need to be addressed before these devices can truly live up to their potential. Text entry, support for a variety of applications, precise selection techniques, and ergonomics are particularly important areas of improvement.

What is an Interactive Tabletop?

Based on the features our respondents rated as most important, we can define an interactive tabletop as "a large surface that affords direct, multi-touch, multi-user interaction." While horizontal orientation is seen as promoting face-to-face collaboration, it poses challenges related to the ergonomics of long-term use. The ergonomics of tabletop displays are not typically discussed in tabletop research literature, perhaps because most evaluations of such systems involve relatively brief periods of use. Morris et al.'s studies of the suitability surfaces for active reading [8] and office tasks [9] are exceptions; they reported that several subjects in their studies complained of neck strain after reading and writing on horizontal displays. Designers of tabletop systems should consider form factors with adjustable height and angle, perhaps enabling the transition between a horizontal "collaboration" configuration and a vertical or angled "personal use" configuration.

Input Solutions Needed

Thus far, studies of which input techniques are most suitable for tabletops systems, *e.g.*, comparisons of styli vs. direct touch, as in [4], did not yield clear prescriptions for what is best. However, the respondents in our survey placed utmost importance on touch input, despite the acknowledged problems of imprecision. That respondents considered tangibles valuable only for initial appeal is surprising since one of the oft-cited benefits of interactive tabletops is that, like traditional horizontal surfaces, they can support object placement and enable the natural use of tangible props [10].

Although text entry and precise pointing were both cited as limitations of tabletop systems, technologies that might alleviate these challenges, such as speech input for text entry or stylus input for more accurate pointing, were ranked extremely low on the list of valued features. Even standard mice and keyboards were only cited for long term single user scenario. Understanding why stylus input is unpopular and investigating other means of enhancing pointing precision on touch surfaces are important areas of further research; [1], [3], and [11] provide good examples of initial forays in this direction. Hinrichs *et al.* [6] analyze the suitability of common text entry techniques for tabletops; the invention and evaluation of novel methods for text-entry on interactive tables remains an open and critical area for further research.

Also, it is our recommendation that serious consideration be given to incorporating standard mouse and keyboard devices into the tabletop interaction workflow in addition to multi-touch interactions. Pursuing this mixed input metaphor might provide a solution to the most pressing interactive tabletop issues.

CONCLUSION

We have presented results from a survey of 58 tabletop researchers and developers. We have contributed data on the respondents' use patterns, on the most- and least-valued features of tabletops, and on obstacles preventing further adoption. Based on these findings, the challenges of text input, pointing precision, and the ergonomics of horizontal surfaces stand out as particularly crucial issues to address before interactive tabletops can see success as instruments for productivity and collaboration.

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