Some Thoughts on Ergonomic, Practical, and Economic Properties of Interactive Tabletops

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Abstract
In order for interactive tabletops to become commercially and socially relevant, they would need to fulfill five requirements: allowing objects to be placed on them, affording to be used as an actual table, becoming affordable, being ergonomically usable, and offering sufficient display resolution. I propose interactive tabletops that employ top-down projection using laser projectors as a way to partially fulfill these requirements.

Author Keywords
tabletop; interactive surfaces; affordances; ergonomics

ACM Classification Keywords
H.5.m [Information interfaces and presentation (e.g., HCI)]: Miscellaneous

Introduction
For this paper I roughly define an interactive tabletop as a surface with the general dimensions of a tabletop which incorporates medium- to high-resolution display capabilities, touch input, and sometimes tracking and recognition of objects on the surface. It can be used simultaneously by multiple physically present users. The main physical differences distinguishing interactive tabletops from other interactive surfaces are their typical form factor and the horizontal orientation of the interactive surface which affords

putting things on it.

In their call for papers the workshop organizers argue that *"[a]fter 20 years of research, it is unclear what role the tabletop should play in the home or workplace. [. . .] in practice tabletops see limited use."*[1]

I can confirm this observation. In my opinion, the issue holding back interactive tabletops is *not* primarily a lack of useful applications for these. A lot of daily activities in the home and in workplaces take place on and around tables. Thus, interactive tabletops can be of manifold use in *supporting* existing applications for dumb tables. But instead of digitally augmenting existing applications for traditional tabletops, we as an academic community and many commercial developers have focused on developing new applications[2] for touchscreens with table legs.

Five Requirements for Interactive Tabletops

In my (current) opinion, the main and ultimate drawback of current interactive tabletops is that they are bad tables, and therefore only of limited use. As I argue above, in many cases, interactive tabletops only have a supporting role within a task involving 'analog' interactions or multiple devices. Therefore, interactive tabletops have to weave themselves into the fabric of everyday lives [5].

In order to become relevant outside of niche applications, interactive tabletops need to afford putting stuff on them, need to be robust, have to be inexpensive, should offer adequate spatial display resolution, and must be ergonomic. Typical interactive tabletops, such as the original Microsoft Surface and Samsung SUR40, fulfill none of these five requirements.

[1] https://thedisappearingworkshop.wordpress.com/cfp/

[2] or clones of existing analog applications, such as map viewers, jigsaw puzzles, or photo sorting demos

In the following I discuss the individual requirements.

Interactive tabletops need to afford putting stuff on them Most interactive tabletops employ embedded screens or back-projection. Therefore, putting stuff on the table makes it impossible to see the screen contents or interact with them. This property severely limits two typical use cases: a) placing devices on the table, such as keyboards, computer screens, or physical inboxes, and b) using tangibles or physical documents together with on-screen documents and widgets.

Interactive tabletops need to be robust As we have argued before [1], a major limitation of most (all?) commercially available interactive tabletops is that they cannot be used the same way as an ordinary table. With an ordinary table, the owner may sit on it, lean on it, cut bread on it, or even stand on it without worrying about breaking it. None of the interactive tabletops that I have used so far would have allowed such uses. Given that floor space is limited in most apartments and offices, users might shy away from sacrificing space for a table that will only be used rarely in its interactive mode and cannot be used at all as an ordinary table.

Interactive tabletops have to be inexpensive Another important issue that limits widespread adoption of interactive tabletops is their price [1]. Here, I believe the issue to be less the price itself but the fact that interactive tabletops combine fragile electronic parts which are subject to fast upgrade cycles with a robust piece of furniture whose upgrade cycles are measured in decades. Also, for many people that I know, furniture has to fit the room - and tastes vary wildly between people and change over time. Therefore, interactive tabletops that people would actually buy

have to decouple furniture and electronics and allow them to be upgraded independently.

Interactive tabletops should provide sufficient display resolution Research on interactive tabletops has been driven and limited by available hardware since its beginning.[3] This focus on hardware - and especially displays - is not surprising because many use cases require visual content being displayed with high resolution. Here, interactive tabletops compete with paper documents and paper maps. Any resolution less than that of ink on physical paper (≈300 dpi) limits the usefulness of interactive tabletops for many typical document interaction tasks, such as annotating and organizing papers. Thus, a *paper-resolution* interactive tabletop with a size of 2 x 1 meters (80 x 40 inches) would require a display with a resolution of 24,000 by 12,000 pixels. Throughout the past 25 years, commercially available display and projection technology has been far from approaching such a pixel count. Insofar, compared to direct interaction with physical paper documents, interacting with digital documents on an interactive tabletop has always been hampered by slow, uncomfortable crutches - such as zoom+pan or overlayed high-resolution displays. Unless an interactive tabletop offers a display resolution that is close to that of paper, it is unable to replace traditional paper-based workspaces.

[3] as mentioned by Wendy Mackay in her TEI 2015 keynote [4] (YouTube video, 7:30 - 9:02: https://youtu.be/0nHdf8MTOTM?t=450), Pierre Wellner developed his seminal Digital Desk [6] after being handed a video projector from an expensive, broken rear-projection TV, and being asked to find some use for it. Jefferson Han's FTIR paper [3] demonstrated a robust, low-cost approach to touch tracking, sparking numerous DIY projects, startups, and research papers building on this approach. Many researchers built on the commercially available Microsoft Surface and Samsung SUR40.

Interactive tabletops must be ergonomic In many cases, people work on traditional tables and desks while sitting in front of them. However, trying to get actual work done on an interactive tabletop while sitting in front of it gets very annoying very fast. The viewing angle makes it hard to read text; the low resolution does not help either. Most of the screen space is only visible in the peripheral vision and requires the user to turn their head all the time. The opposite edge of the screen may be hard to reach while sitting, typing on a touch screen is uncomfortable and may start hurting over time, and putting a physical keyboard on the tabletop obscures important screen content. With our Curve concept [7] we presented an approach for improving ergonomics of interactive tabletops by merging a horizontal 'tabletop' surface and a vertical 'computer screen' surface. While this approach still seems promising, its implementation was limited by the same general issues documented above.

Laser projectors for implementing acceptable interactive tabletops

Given the requirements listed above, and with respect to currently or shortly available hardware, the most promising approach for building interactive tabletops might be to employ laser projectors mounted on the ceiling and projecting down onto a standard table. This has the following benefits:

- objects on the table do not occlude the screen contents (but might distort them); in addition, they can be visually augmented by the projection
- the table can be used as usual without worrying about scratching or breaking its surface
- table and display electronics can be chosen and upgraded independently
- as scanned laser projectors and other types of laser

projectors offer a very wide focus depth[4], non-planar and flexible surfaces can be used as display, allowing for more ergonomic form factors, such as presented with Curve [7].

- *scanned laser projectors* [2] allow for dynamically adjusting resolution and field of view depending on the needs of the current application

Laser projectors with 4K resolution are currently becoming commercially available (see, e.g., the recently announced Dell S718QL). Due to the ergonomic, technical, and economic reasons outlined above, I believe that augmenting existing tabletops with high-resolution projections is the way to go for many interesting applications.

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[4] see e.g., http://www.kguttag.com/2012/01/27/laser-with-lcos-is-focus-free/