Interactive Gigapixel Prints: Large, Paper-Based Interfaces for Visual Context and Collaboration

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ABSTRACT
For centuries, large paper information graphics such as maps have been important cognitive artifacts in navigation, architecture, engineering, and scientific work. Paper-based practices leverage the reliability, affordability, readability, mobility, and flexibility of paper—yet lack the interactivity afforded by digital technologies. This video introduces Interactive Gigapixel Prints (GIGAprints), computer controlled large-scale paper displays. When combined with a digital pen, these prints enable users to capture handwritten content. When augmented by digital displays, these prints integrate the high *spatial* resolution of wide-format printing with the high *temporal* resolution of digital displays. By having paper and digital displays work together as an ensemble, GIGAprints provide the best of both worlds.

ACM Classification Keywords
H.5.2: User Interfaces—*input devices and strategies; interaction styles; prototyping.*

Keywords
Augmented paper, large displays, device ensembles.

INTRODUCTION

Interactive Gigapixel Prints combines wide-format printing, digital pens, handheld displays, and LCD projectors to create augmented paper interfaces. The printer creates large paper displays; digital pens enable users to input directly on the printed surface; and digital displays provide for interactive content (see Figure 1). GIGAprints was inspired by large, information-rich paper documents — from Imhof's cartography, through Kerouac's 120-foot long *On the Road* manuscript, to the high resolution photos from the Gigapixl Project. By integrating printed displays with overlaid projection or adjacent mobile devices, GIGAprints leverages both the centuries of study in printed visualization [8], and the more recent research into interactive visualization [3].

Prior work (*e.g.*, [4, 7]) has shown that the affordances of paper have encouraged its significant use, even in today's technology-enabled world. Paper-based visualizations offer users a sense of *familiarity*. They are *ubiquitous,* and afford *mobility* and *flexibility* — an archaeologist can sketch directly on a map. Paper provides *robustness*; it never requires batteries, and can survive damage in the field. The *high resolution* of printing reveals nuanced imagery. The

Figure 1. The Interactive Gigapixel Prints ensemble: wide-format inkjet printers, digital pens, and digital displays. This ensemble supports ambient awareness, visual context, and collaboration.

size of some printed visualizations renders zooming unnecessary; we can achieve detail, not by manipulating a graphical slider, but by drawing nearer to the print. Large physical sizes also enable synchronous and collocated *collaboration*. Finally, paper's *physicality* and *tangibility* enable users to leverage their spatial reasoning and navigation abilities.

INTERACTING WITH GIGAPIXEL PRINTS

Since Wellner's DigitalDesk [9], there has been significant interest in integrating physical and digital interactions. GIGAprints improves upon this work by contributing support for mobility, and for output via printing. This research also explores the space of physical-digital interactions. In 1974, Foley and Wallace suggested that interactions with a *graphical* interface fall into one of four categories: *pick*, *button*, *locate*, and *valuate*. Variations on this taxonomy have been used to guide input architectures such as Interactors [5]. Broadly speaking, these taxonomies specify a *select* operator and several *manipulate* operators. GIGAprint interactions can be described similarly, with the addition of two operators that facilitate inter-device communication.

- S*elect* enables a user to employ the sender device to designate objects of interest on the receiver device.
- *Manipulate* is a term for the set of operations that enable the sender to modify content on the receiver.
- *Associate* creates a link between information on the sender and a information on the receiver.
- *Transport* moves content from sender to receiver.

The GIGAprints technology can incorporate digital displays in several ways. For augmenting prints with real-time output, GIGAprints leverages mobile devices, LCDs, and projectors. Our prototype employs a wide-format inkjet printer (the 44" Epson Stylus Pro 9800), and Anoto digital pen technology [1]. The pens we use (the Nokia SU-1B) stream data in real-time to the GIGAprints server. We use the OQO 01+ to prototype a mobile phone.

APPLICATIONS

We demonstrate the GIGAprint interactions through 1) a photo wall, 2) a network monitoring tool, and 3) a map-based querying system. In the examples, the *pen* provides selection, filtering, and annotation. The *printer* generates large, high resolution content. The *projector* or the *mobile device* provides the real-time information.

Photo Wall

This application, which renders a set of photographs onto a large paper surface, was inspired by the visibility of work in publishing houses [2]. For organizations that operate on short time cycles, where finding the "right" image for the front page can be difficult, a large, high-resolution photo wall may prove invaluable. Users can engage the photo wall in several ways. As an *ambient* display, that never requires electricity, the photographs are always visible. Multiple users can also discuss photos in a synchronous, collocated manner. A passerby can *select* a photo with a digital pen to *transport* it to her mobile device. Users do not need to navigate web pages; scrolling and paging becomes a visual search task on this GIGAprint.

Network Awareness

Our colleagues in information visualization are currently researching network visualization techniques (*e.g.*, [6]); this GIGAprint application is a result of our collaboration. It hangs in our laboratory, increasing the awareness of network activity. The print (3-feet wide by 6-feet tall) comprises three types of content. First, the print displays a grid of 225 graphs, each showing the recent activity of a single machine. Second, the print displays a grid of 135 ISPs that these machines have had communications with. In total, this represents 561,000 data points. This print also presents five paper widgets that enable users to invoke commands.

With the pen, the user can report unusual machines by tapping the *email* widget and then selecting the machine. Users may also write notes on the print itself. We have also built interactions involving a mobile device. While computer names are anonymized on the public visualization, a network admin must be able to access the details. To do this, he taps on a computer name with his pen. Information for that computer is then displayed on his handheld. Rich interactions are also available through geo-referenced integration of the print with a projector. In this application, the projector acts as a targeted spotlight to provide real-time information both *ambiently* and in *response* to user queries.

Map-based Queries

Maps have long been one of the prime benefactors of the resolution, size, mobility, and flexibility of print media. We designed two map-centric interactions. First, map-based capture enables a user to write directly on the map while they are in the field. The digitized handwritten notes are displayed in the ButterflyNet browser [10]. Second location-based queries enable users to retrieve geo-tagged photographs from a database by selecting a location on the map; the matching photos appear on the user's handheld.

CONCLUSION

We have described Interactive Gigapixel Prints, large printed surfaces that are augmented with digital displays. GIGAprints provides interaction techniques that enable users to leverage the benefits of both the print and digital media. Our examples are only a subset of what is possible with GIGAprints. The software is open source, and available at http://hci.stanford.edu/gigaprints.

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REFERENCES

1 Anoto AB, *Anoto Technology*. http://www.anoto.com
2 Bellotti, V. and Y. Rogers. From Web Press to Web Pressure: Multimedia Representations and Multimedia Publishing. *CHI: ACM Conference on Human Factors in Computing Systems*. pp. 279–86, 1997.
3 Card, S. K., J. Mackinlay, and B. Shneiderman, *Readings in Information Visualization: Using Vision to Think*: Morgan Kaufmann. 712 pp. 1999.
4 Heath, C. and P. Luff, *Technology in Action (Learning in Doing: Social, Cognitive & Computational Perspectives)*: Cambridge University Press. 286 pp. 2000.
5 Myers, B., S. E. Hudson, and R. Pausch. Past, Present, and Future of User Interface Software Tools. *ACM Transactions on Computer-Human Interaction* **7**(1). pp. 3–28, 2000.
6 Phan, D., L. Xiao, R. B. Yeh, P. Hanrahan, and T. Winograd. Flow Map Layout. *InfoViz: IEEE Symposium on Information Visualization*: IEEE Computer Society. pp. 29-38, 2005.
7 Sellen, A. J. and R. H. R. Harper, *The Myth of the Paperless Office*. 1st ed: MIT Press. 242 pp. 2001.
8 Tufte, E. R., *The Visual Display of Quantitative Information*. 2 ed: Graphics Press. 197 pp. 2001.
9 Wellner, P. Interacting With Paper on the DigitalDesk, *Communications of the ACM*, vol. 36(7): pp. 87–96, 1993.
10 Yeh, R. B., C. Liao, *et al.* ButterflyNet: A Mobile Capture and Access System for Field Biology Research. *CHI: ACM Conference on Human Factors in Computing Systems*. pp. 571–80, 2006.