MagPad: A Near Surface Augmented Reading System for Physical Paper and Smartphone Coupling

Ding Xu[1], Ali Momeni[1], Eric Brockmeyer[2]

[1] Carnegie Mellon University
5000 Forbes Avenue, Pittsburgh, PA 15213
dx@andrew.cmu.edu, momeni@cmu.edu

[2] Disney Research Pittsburgh
4720 Forbes Avenue, Pittsburgh, PA 15213
eric.brockmeyer@disneyresearch.com

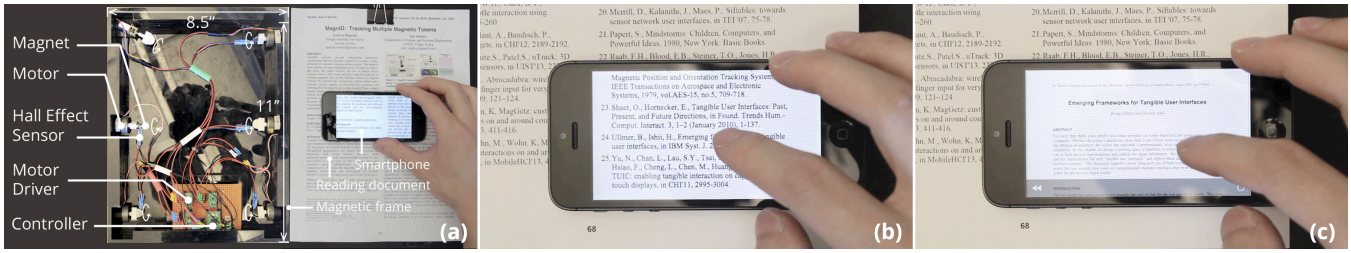

Figure 1. A hybrid ensembles of smartphone and paper document for augmented reading. (a) spinning magnets frame and system arrangement; (b) the smartphone shows occluded content; (c) a user read reference by clicking on a citation

ABSTRACT

In this paper, we present a novel near surface augmented reading system that brings digital content to physical papers. Our system allows a collocated mobile phone to provide augmented content based on its position on top of paper. Our system utilizes built-in magnetometer of a smartphone together with six constantly spinning magnets that generate designed patterns of magnetic flux, to detect 2D location of phone and render dynamic interactive content on the smartphone screen. The proposed technique could be implemented on most of mobile platforms without external sensing hardware.

Author Keywords

Augmented reading, Smart lens, Active magnetic sensing

ACM Classification Keywords

H.5.1 Artificial, augmented, and virtual realities; H.5.2 User Interfaces - Input devices and strategies.

INTRODUCTION

Paper and mobile devices both have their advantages for reading. Physical paper offers spatial arrangement, tangibility and affordance [1-3]. It also provides a good mental representation for comprehension and memory [4]. In contrast, mobile devices excel at providing dynamic multimedia content, allowing vast storage and easy sharing; but have limitations on screen size and display resolution [2-3].

Paper and mobile devices are used in parallel in different scenarios and sometimes are complementary to each other. Research shows that close distance between smartphone and reading documents is preferred in order to create a joint focus zone in such hybrid ensembles [7]. However, most prior augmented reading systems employ computer vision technologies that require a smartphone to be some distance above the paper document in order for its camera to capture a good image [2-3], a limitation that was identified in [5]. We focus on coupling physical documents and digital content together through interactions that do not require hovering the smartphone above the paper document, in order to lower switch time between physical and digital content and to facilitate a more focused reading experience.

We propose MagPad: a near-surface interaction system of augmented reading for physical paper and smartphone coupling. The MagPad employs an optical metaphor where a lens displays the content it frames but also reveals additional information. In our system, the smartphone shows the physical content it occludes on the screen, but also responds to users' input, layers additional digital content, or directs the user to related information. Our proposed interaction shortens the time required to switch from one medium to another; reduces physical handling efforts; and provides a location-based content rendering in effort to overcome the limited screen size of smartphones.

IMPLEMENTATION

We proposed a low cost active magnetic sensing technique to predict 2D location of a smartphone using spinning magnets based on the idea proposed in [6]. Our system is comprised of a physical frame that sits beneath the paper

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document and contains six DC motors around its perimeter (Figure 1a). Each DC motor spins a permanent magnet at a predefined frequency (3.5Hz, 6Hz, 8Hz, 10Hz, 12.5Hz and 15Hz) held constant with a Hall effect sensor-based feedback control system. Each spinning magnet generates a periodic sinusoidal magnetic flux throughout the reading area. As the mobile phone is moved around the reading area, the amplitude of each frequency band indicates the distance between the corresponding magnet and the smartphone.

A smartphone app samples the phone's magnetometer at 100Hz and streams the data to a laptop using the OpenSoundControl protocol [8] for signal processing and location recognition. FFT analysis of this data (128 samples, Blackman window) extracts spectral information about the magnetic flux. We construct our feature vectors from the energy in the first 32 bands of the FFT, along with statistical analysis of the FFT data (band ratio, mean, variance, maximum band amplitude and index, kurtosis). We train a SVM classifier to first predict the current quadrant (i.e. top-left, top-right, bottom-left, bottom -right); subsequently, two SVM regression models are trained and loaded to predict x and y location within the quadrant.

Finally, we use a photo or existing digital version of the physical document to dynamically render the corresponding part of the content on-screen and at scale once smartphone's location is updated (Figure 1b).

APPLICATION

References reading for academic paper

In this application, we combine the tactility, legibility and spatial arrangement of paper documents with a smartphone's ability to present dynamic content. We focus on providing extended content based on references section of an academic paper. When a user moves a smartphone over the reference section and clicks on a citation, the application displays corresponding PDF on screen (Figure 1b, 1c). This application offers an efficient way to present relevant digital content next to physical document for hybrid reading.

Translation

In this application we focus on scenarios where only physical version of document is available. A photo of physical page is captured, analyzed using optical character recognition and scaled to generate a digital version before reading. When a user comes across unfamiliar words or sentences while reading the physical text, the smartphone can be placed on that area and act as a prompt translator for selected words or sentences on screen (Figure 2a).

Social annotation

In this application we focus on collaborative social annotation (Figure 2b) where the users is able to discover, read and contribute to text annotations stored in the cloud for a given document. The smartphone is used as a digital layer to show or hide public comments by placing or removing smartphone on certain position. This enables users to read physical document but save annotations digitally and in the cloud.

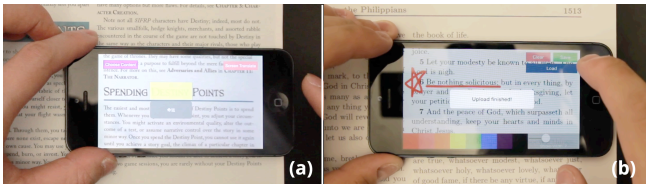

Figure 2. Demo applications (a) translation (b) social annotation

CONCLUSION

In this paper, we proposed a low cost technology and three applications for a near surface augmented reading system pairing physical documents with a smartphone. Our proposed interaction shortens the distance and lowers the switch time between physical text and digital content, and provides a responsive content display based on mobile device's location. As the development of context aware sensing technologies, we believe our system can bring much potential of bridging digital services to our physical reading with new interactions.

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