
Pulp-Based Computing: A Framework for Building Computers Out of Paper

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Abstract

In this video, we describe a series of techniques for building sensors, actuators and circuit boards that behave, look, and feel like paper. By embedding electro-active inks, conductive threads and smart materials directly into paper during the papermaking process, we have developed seamless composites that are capable of supporting new and unexpected application domains in ubiquitous and pervasive computing at affordable costs.

Keywords

Paper, smart materials, composites, ubiquitous computing, sensors, actuators.

ACM Classification Keywords

H.5.2 User Interfaces: Theory and methods.

Introduction

Before the advent of computers, paper was the substrate of choice for storing, organizing and transmitting information. Its durability, coupled with the versatility of the printing press, became a pivotal force in the cultural, economic and scientific developments that permeate most of our life. Despite claims that flexible and non-emissive display and input technologies will eventually render paper obsolete, the

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technologies haven't matured enough to fully replace books, newspapers, or notepads [1]. Moreover, these technologies usually overlook the material qualities and interaction affordances that are at the core of paper's versatility. Paper sheets can be bent, folded, shredded, recycled, stapled and written on at a very low cost and without the need for software upgrades or everlasting battery supplies. Building upon this potential, we have developed electronic paper composites, which combine traditional papermaking techniques with the interaction possibilities of smart materials.

Paper Composites

A composite material is a combination of two or more materials that have different physical or chemical properties, but together yield unique characteristics, while retaining the strengths and particularities of its constituent elements. By embedding electro-active materials into paper during the papermaking process, it is possible to create sensors and actuators that convey the affordances and tactile qualities of paper, while leveraging the potential of computers.

Papermaking

Whereas industrial papermaking processes are highly mechanized and produce large quantities of paper, its handmade alternatives are laborious and time consuming activities. However, handmade paper allows for an inclusion process, where a physical object can be permanently embedded in between two individual paper sheets which are then compressed, drained and set to dry. By silk screening and encapsulating electrically active inks in between sheets, it is possible to create an electronic paper "sandwich" which is resilient and inseparable from its embedded object [3]. Rather than simply depositing ink on a sheet's surface,

which is prone to chipping and breaking [4], our process encapsulates the ink particles in-between wet paper sheets. When the sheets dry and shrink, they compress the inks, keeping them protected from external stresses. The result are sensors and actuators that are more resilient, reliable and electrically insulated. This video features several of the paper technologies we have developed, in particular a paper-based speaker, bend sensor and emissive display.

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References

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figure 2. Composite combining natural paper and electronic components [2].