Bendable Color ePaper Displays for Novel Wearable Applications and Mobile Visualization

Konstantin Klamka¹, Raimund Dachselt¹²
¹ Interactive Media Lab, Technische Universität Dresden ² Centre for Tactile Internet with Human-in-the-Loop (CeTI)

Abstract
We present a toolkit that allows to easily prototype with bendable color ePaper displays for designing and studying novel body-worn interfaces in mobile scenarios. Therefore, we introduce a platform that enables researchers for the first time to implement fully-functional wearable and UbComp applications with interactive, curved color pixel displays. In detail, our prototype supports the development with Arduino and support versatile wireless protocols.

To put it in a nutshell, we contribute:
- A basis for further research. In detail, the parts are
  - Detailed Building Instructions & Documentation
  - Implemented Example Applications
- A set of pre-programmed functional example apps
- Good range of sensors, e.g., 9-DoF motion, temperature, humidity, noise, light, gesture sensors that are built-in, battery-powered display

We introduce a wearable research toolkit to easily prototype with bendable and color ePaper displays.

E-PAPER TOOLKIT & PROTOTYPE
We introduce a wearable research toolkit to easily prototype with bendable color ePaper displays.

IMPLEMENTED EXAMPLE APPLICATIONS
To validate the technical feasibility and demonstrate the potential of our toolkit, we present 8 example apps.

RESEARCH ROADMAP
Finally, we take a glimpse into the future and discuss promising directions for colored ePaper displays.

Detailed Building Instructions & Documentation
In order to make our toolkit accessible, we provide detailed building instructions and a documentation to enable researchers to replicate our prototype. To do so, we present step-by-step video instructions, list all parts and publish the Arduino-based source code as a basis for further research. In detail, the parts are
- Customizable curved display housing
- Flexible explicit pressure touch module
- Wiring & circuit diagrams of all electronics
- Source code with helper classes & examples

Implemented Example Applications
To validate the technical feasibility and demonstrate the potential of our toolkit, we introduce eight example apps. All apps serve us as a technological as well as conceptual foundation for further research. Additionally, they also could inspire new fields of application beyond wrist-worn devices and will help to quickly bootstrap new projects by building on the set of pre-programmed components (e.g., graphical widgets, sensor & wireless integration).

- Versatile Connectivity based on Bluetooth LE
- Native HID Media Keys, Apple Notification Center Service
- Built-in Environmental & Motion Sensors
- 9-DoF motion, temperature, humidity, noise, light, gesture sensors that are built-in, battery-powered display
- Functional Real-World Apps
- Sensor-based apps, e.g., steps, weather, media controls, e.g., music & presentations via sensors (via ANCS) (via HID)

For future work, we plan to move forward in several research directions.

- Advanced Mobile Visualizations
  We think that the further investigation of aesthetic, meaningful and color ePaper data visualizations are yet underexplored, but important and promising, building blocks for future wearable interfaces. Therefore, we plan to extend our InfVis app and study color-encoded, real-world data visualization in depth.

- New Form Factors
  We are looking forward to go beyond the wrist and explore new, exciting form factors and flexible hybrid composites. Moreover, we envision a bright future for color-changed EPODs and films as a display material for accessories or interior designs using folded, non-planar and polygonal structures.

- Conducting Field Studies
  Conducting Field Studies is a challenging, however also very valuable method to gain empirical insights and investigate prototypes in their envisioned context of use. Therefore, we plan to study applications beyond the lab and deploy research prototypes to end users to better understand possible design issues.

Display Research Toolkit
Our easy-to-use, Arduino-based, battery-powered display toolkit enables researchers to realize fully-functional and versatile mobile applications which are ready-to-use for field studies.
- Wearable prototype and Arduino software stack
- A set of pre-programmed functional example apps

Advanced Color ePaper Display (EPD) from Plastic Logic with AdvancedColor (ACeP) ePaper technology providing four color pigments (red, blue, green, yellow) plus black and white.
- 240 x 146px, 132 PPI, bending radius ~30-40mm
- SPI interface, full refresh time 15s

We built on a bendable active-matrix electrophoretic display (EPD) from Plastic Logic with AdvancedColor (ACeP) ePaper technology providing four color pigments (red, blue, green, yellow) plus black and white.

The Partially Enclosed Case
We designed a curved case that can be easily customized with sensory-rich materials such as suede, Japan paper, or bindery cloth by (laser) cutting and gluing on custom cover templates. Versatile mounting options allow to wear the display with elastic bands, combine it with (smart) watches or use it as a stand-alone device.

Activity & Pedometer Weather Forecast Mobile DataVis Interactive Watch Straps
- Notification & Events Quick Access Controls Aesthetic Patterns Professional & Work Wear

Functional Real-World Apps
Sensor-based apps, e.g., steps, weather

Native HID Media Keys, Apple Notification Center Service

Adalfruit Feather nRF52840 Sense Plastic Logic Logic Display Spectra Symbol Soft Membrane Potentiometer

Built-in Enviromental & Motion Sensors
9-DoF motion, temperature, humidity, noise, light, gesture sensors that are built-in, battery-powered display

Flexible explicit pressure touch module
Wiring & circuit diagrams of all electronics
Source code with helper classes & examples

Implementation of pre-programmed components (e.g., graphical widgets, sensor & wireless integration).

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Project Website: imld.de/epaper