

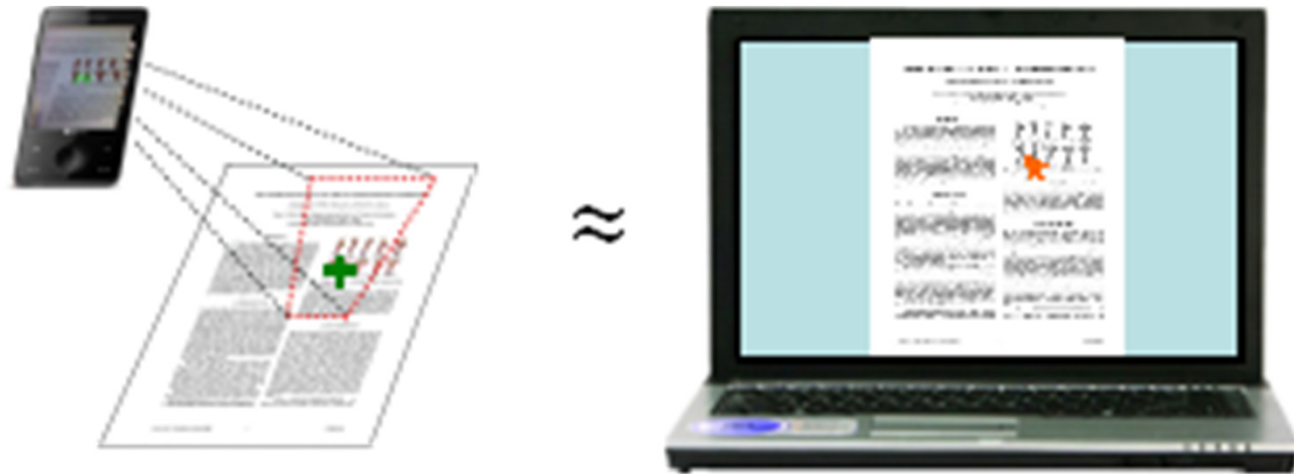
PaperUI

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Why Paper Related Research

- Paper is one of the most widely used communication media and will continue to be used in our daily life for a very long time
 - Paper is an essential part of our daily life
 - Paper production provides a cost efficient way to use wood mill wastes
 - Paper can be recycled or decomposed much easier than most plastics or electronic-devices
 - The world produces approximately 300 million tons of paper each year
 - Every US office employee generates approximately 9,999 more paper sheets each year
 - Many e-products finally stimulate paper usage and create more e-wastes and plastic wastes beyond paper in the past 40 years

PaperUI Concept



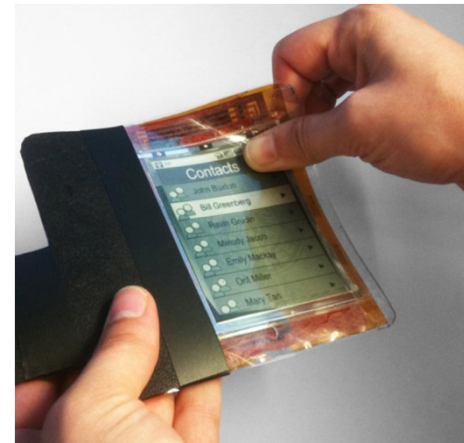
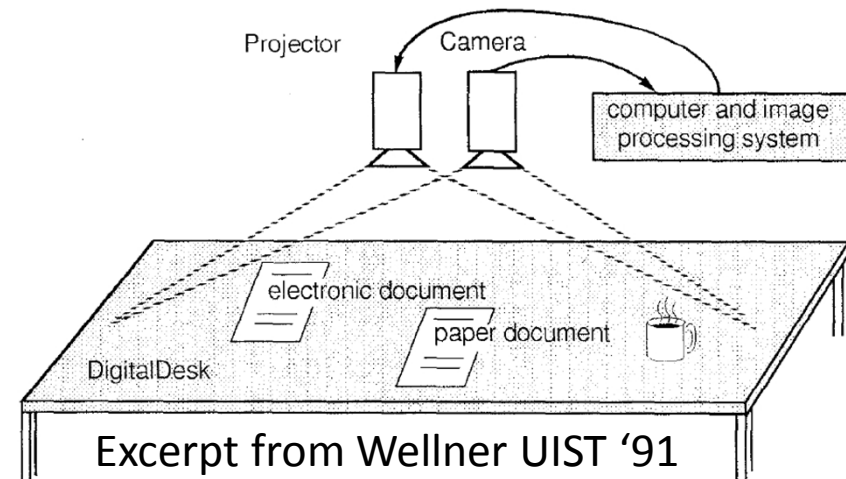
- PaperUI is a human-information interface concept that advocates using paper as displays and using mobile devices, such as camera phones or camera pens, as traditional computer-mice.

Why PaperUI

- To make more efficient use of paper products as well as novel electronic devices, new technologies are demanded to combine the merits of both paper and electronic devices. PaperUI is an initial attempt to address this issue.
- Compared with traditional laptops and tablet PCs, devices involved in the PaperUI system are more light-weight, readable, compact, energy efficient, and widely adopted. Therefore, we believe this interface vision can make computation more convenient to access for general public.

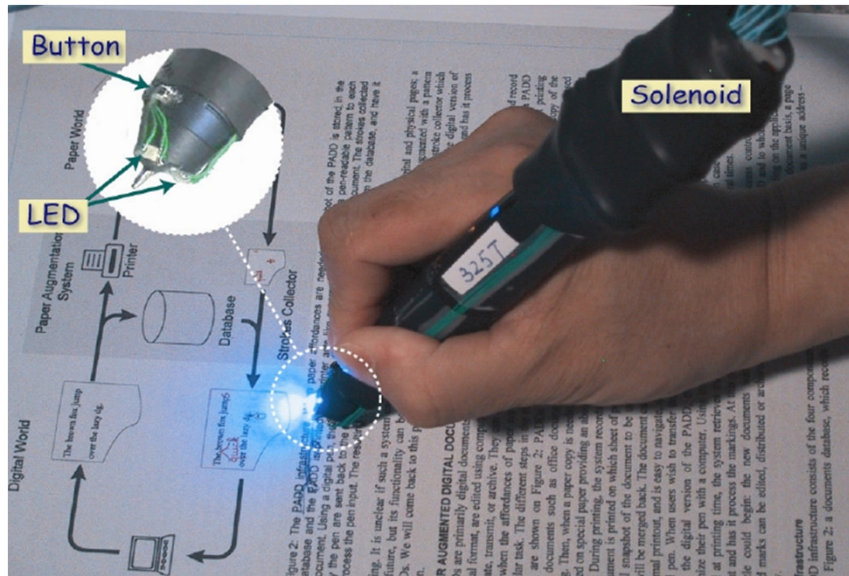
PaperUI Overview

- PaperUI can be situated in the design space of interactive paper systems.
- PaperUI concept offers more considerations to system mobility, interaction resolution, and energy efficiency.
- Different from interactive paper computer.



Excerpt from Science Daily 2010

Different Portable Devices for PaperUI



- Anoto Pen already has commercial applications
- Users need an special device
- Visual feedback is limited

- Smart phones are widely adopted
- Smartphone-based interface has an extra display for visual feedback

Emerging Technologies for Realizing the PaperUI Concept

- Barcode
- Micro optical patterns
- Encoded Hidden Information
- Paper Fingerprint
- Character/Word Recognition
- Local Image Features
- RFID-based Document Recognition

Barcode

- Used by most people
- Nearly unbeatable robustness and affordance
- Not much information for user
- Visually obtrusive
 - May interfere with the document content layout when multiple links are needed
 - May increase paper waste
- It is possible to print semi-transparent barcode with meaningful information to users (ICMI 2010 Liu et al.)

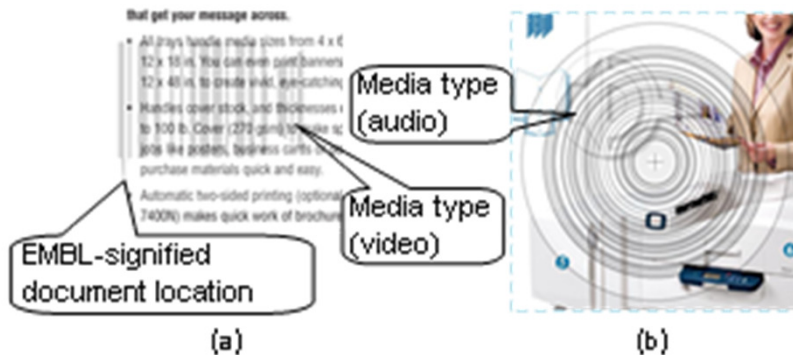


Figure 1. EMBL Examples. Excerpt from Liu et al. [38]

What is EMBL?



- EMBL is a semi-transparent media-icon-modified barcode overlay on paper document content for linking to associated media.
 - *Use iconic information to reveal media information to human*
 - *Use semi-transparent form to reduce interference to content and move closer to EMBL signified location*
 - *Use semi-transparent barcode to identify document patches*
 - *Barcode can be horizontal, diagonal, vertical, or circular*

that get your message across.

- All trays handle media sizes from 4 x 6 to 12 x 18 in. You can even print banners 12 x 48 in. to create vivid, eye-catching
- Handles cover stock, and thicknesses up to 100 lb. Cover (270 gsm) to make special jobs like posters, business cards or photo purchase materials quick and easy.
- Automatic two-sided printing (optional 7400N) makes quick work of brochure

EMBL-signified document **location**

Media **type** (video)



Media **type** (audio)

Problem Abstraction for EMBL Authoring



- Each document patch may be considered as a communication channel
- Embedded barcode is the signal
- Document contents and iconic marks are noises
- EMBL authoring tool
 - Find a proper channel for barcode transmission with proper content-barcode blending
 - Select a proper barcode type

EMBL Research



- **Find the document patch (channel) with lowest noise around a EMBL signified-location for barcode transmission with minimum magnitude (maximum transparency and least interference to document).**
- Guidance from the Shannon-Hartley theorem

$$C = B \log_2 \left(1 + \frac{S}{N} \right)$$

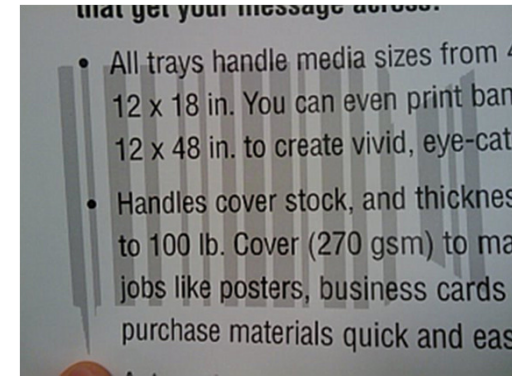
- Assumption: if the barcode channel's SNR is over a certain limit, we can get a reasonable barcode identification rate.

Some Preliminary Experiments – Vertical Barcode **FX**PAL



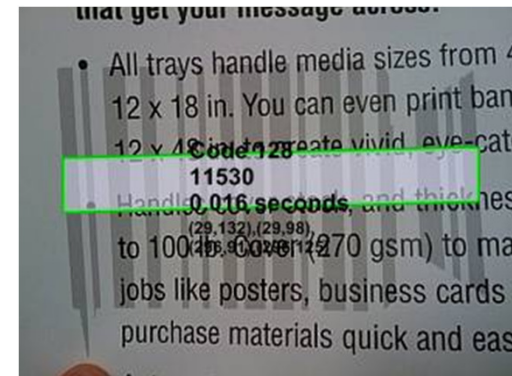
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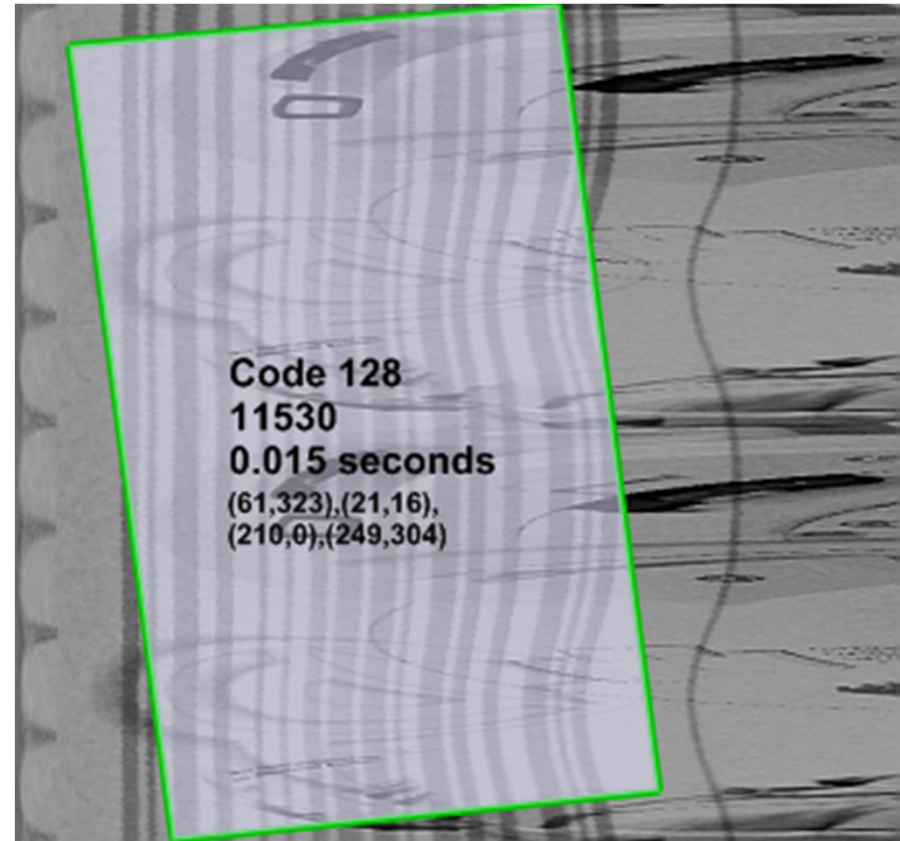
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Some Preliminary Experiments – Circular code



↑
Angle



Radius →

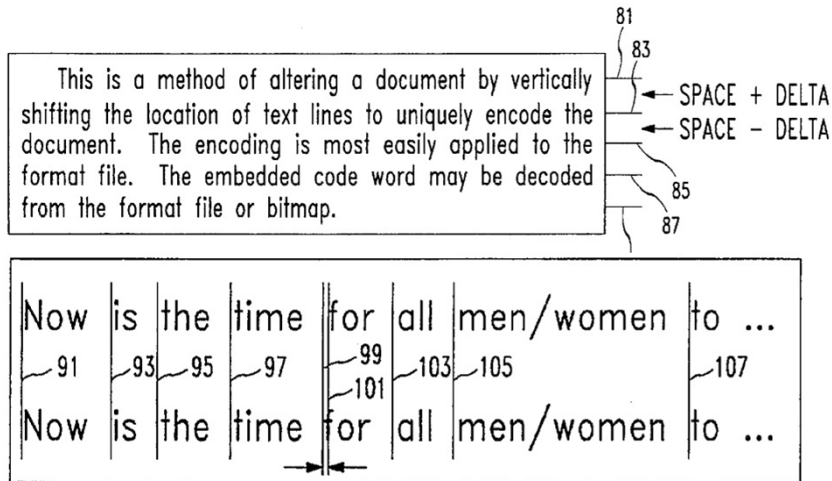
If the center is not located accurately, we will get many curves instead of straight lines. We can submit multiple slices of the transformed image.

Micro Optical Patterns



- Dataglyph and Anoto dot pattern
- Identification accuracy is high
- Much smaller in size
 - Dataglyph – 1/100"
 - Anoto dot grid – 0.3mm
- Less intrusive than traditional barcodes and better localization
- High-res (600-1000dpi) printer & camera
- Hard to use camera phone for pattern capture
- Reduce image contrast

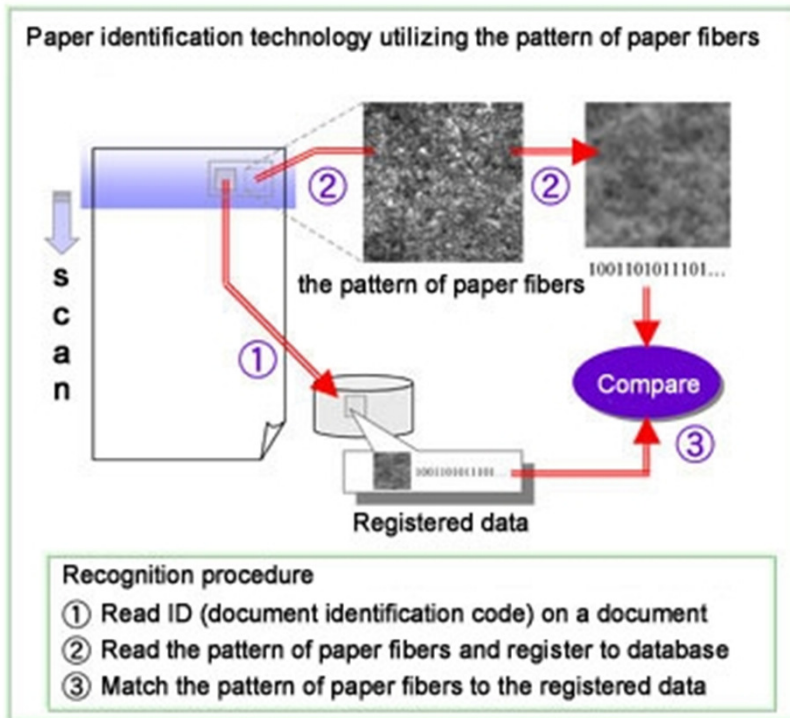
Encoded Hidden Information



- Shift line upwards or downwards by very small amount
- Shift words horizontally to modify the spaces between words
- Less adaptive to a big variety of document contents
- Crosstalk between the watermark signal and host signal is a common problem



Paper Fingerprint

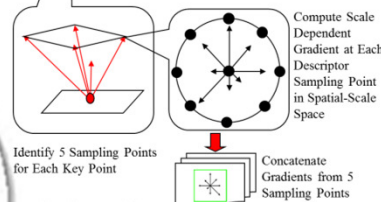
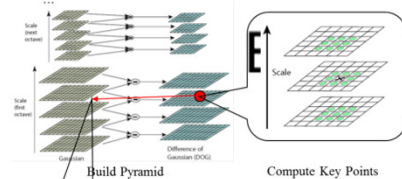
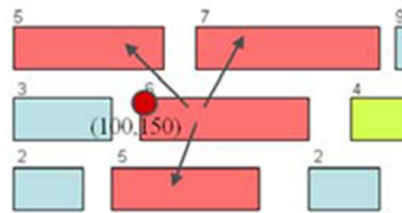


- Paper is composed of fine fibers entangled with each other.
 - Very durable
 - Have very low probability to be identical
- Wood fibers are normally much smaller than basic units of micro-optical-patterns
- No error correction

Local Image Features



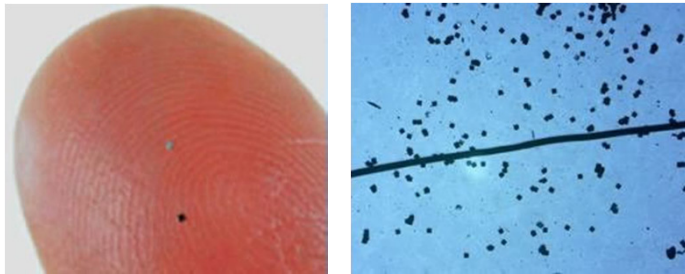
SIFT



Embedded
Media
Marker

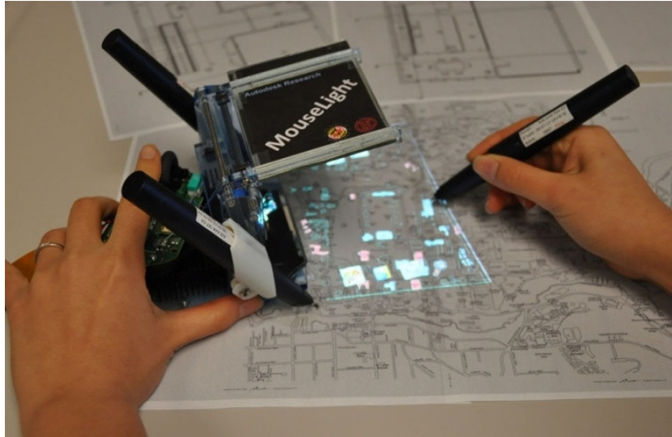
- Spatial layout based feature.
- Pixel level image features
- No exclusive space demand for marker printing
- No demand for changing printing procedure
- Most of them can work on cameraphone images
- Assist us to accurately locate crosshair so that the crosshair can be used as a mouse pointer

RFID-based Document Recognition



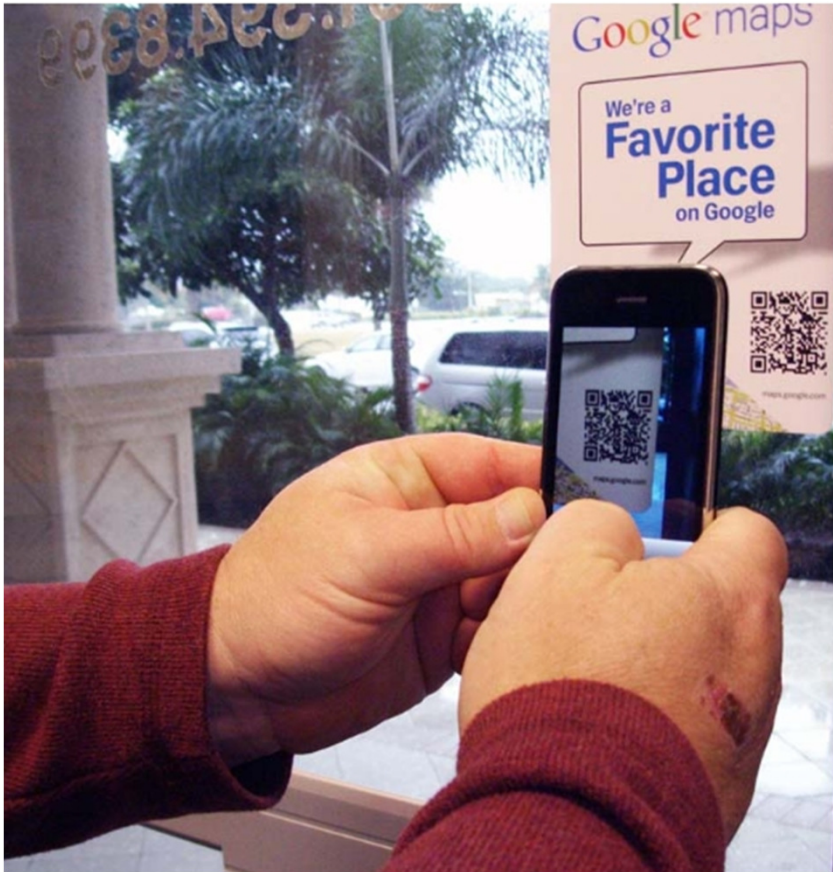
- RFID chips are small enough to be embedded in sheets of paper
- Allow users to interact with paper at a distance
- Fast response speed
- Special printer need to be developed for accurately “printing” these RFID devices on paper
- More portable RFID identification devices
- Technology that can avoid RFID interferences from other pages
- Identify the user selected RFID from proximate RFIDs
- How to estimate pointing direction?

Digital Pen Based Applications



- Form filling
- Convert notes to text and upload documents
- Sync note taking and audio recording, photo capture, GPS
- Music, calculator, language study
- Retrieve additional info, copy-paste, section view, 3D model navigation
- Device control
- ...

Barcode Based Applications



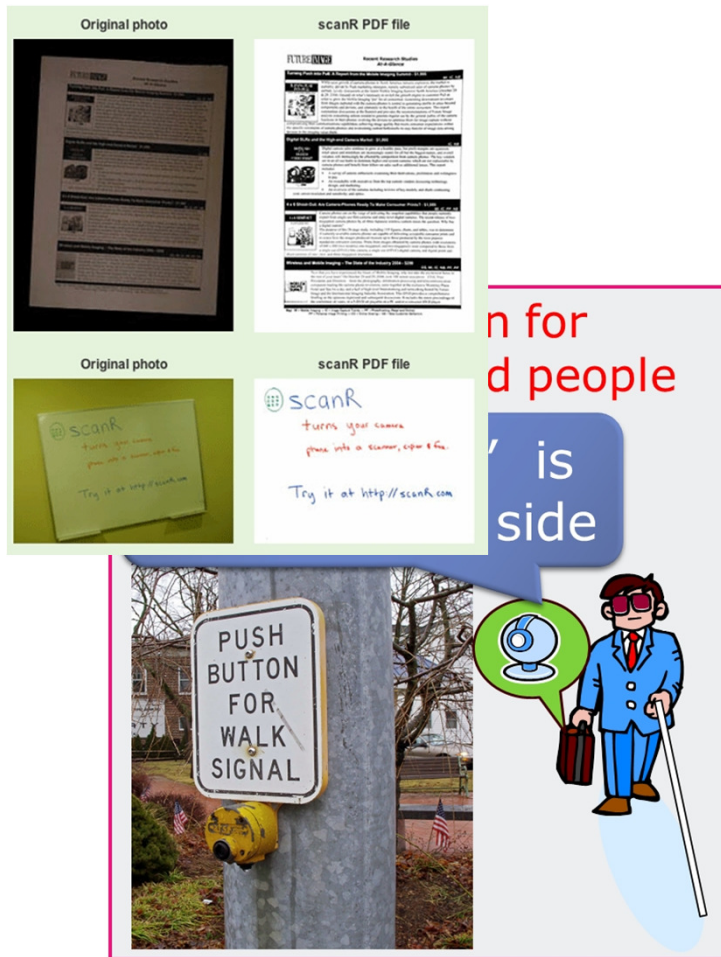
- Compare product price
- Read reviews
- Acquire coupons
- Navigate a city guide or map
- Get athletes' videos, pictures and fan data from a poster
- Read additional contents linked to an IEEE article
- Menu selection
- ...

RFID Based Applications



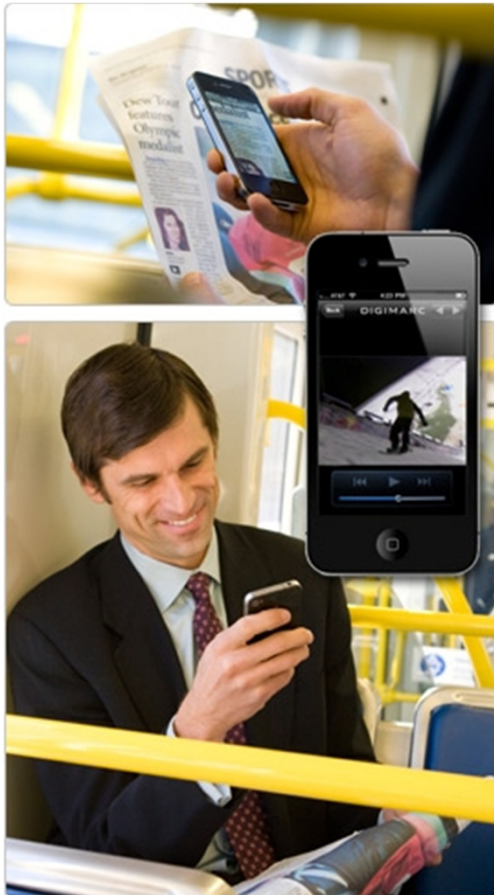
- Get digital information of a map region
 - Restaurant
 - Hotel
 - Shopping center
 - Accurate transit
 - Upcoming shows
 - ...

Character/Word Recognition Based Applications



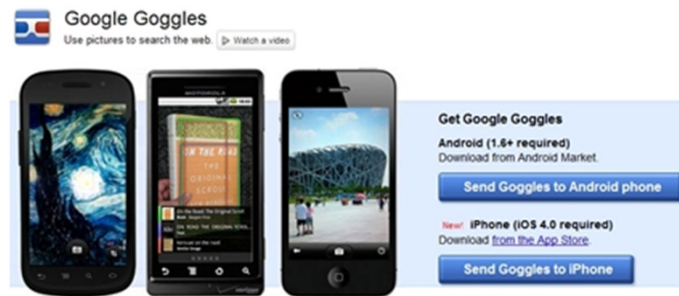
- Convert a camera phone image of a hardcopy into PDF for search, editing, email, text to audio translation
- Translate the card into digital information and add that information into address book
- Translator for foreign restaurant menus, posters

Encoding Hidden Information Based Applications



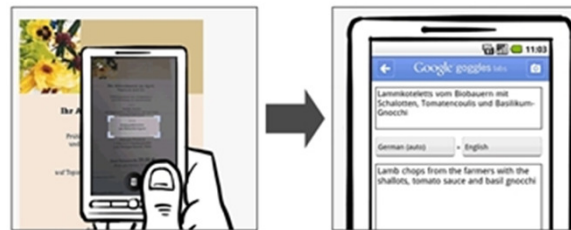
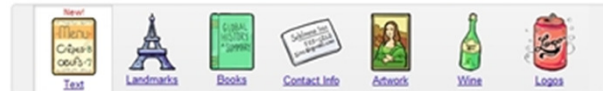
- DigiMarc - invisible
- Uses a small visible icon to remind users about the extra data existence
- Bring videos, interaction widgets, and other multimedia information to a cameraphone via capturing a DigiMarcTM encoded paper page
- Find product coupons, compare product price, and find product stores via capturing a product package

Original Document Feature Based Applications



Google Goggles in action

Click the icons below to see the different kinds of objects and places you can search for using Google Goggles.



Learn more in the [Mobile Help Center](#) or ask questions in our [Help Forum](#).

- Book/CD/DVD/Game search
- Artwork search
- Interactive story telling
- Ad capture initiated store navigation
- Get remote weather info from map

Original Document Feature Based Applications



Ricoh "HotPaper"

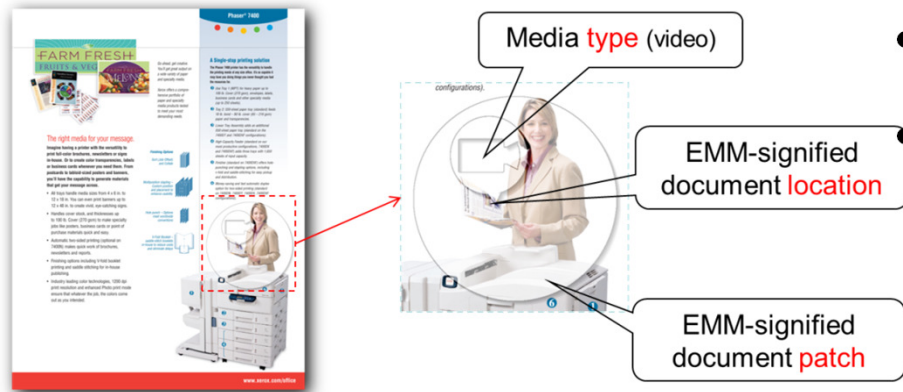
Link personal media to text.
Use BWC (Brick Wall Coding)
Only works on Western text
ACM Multimedia 08



University of Oldenburg "Bookmarkr"

Link photobook picture to digital photo.
Use SIFT features
ACM Multimedia 08

Problems of Using Original Features



- Issues

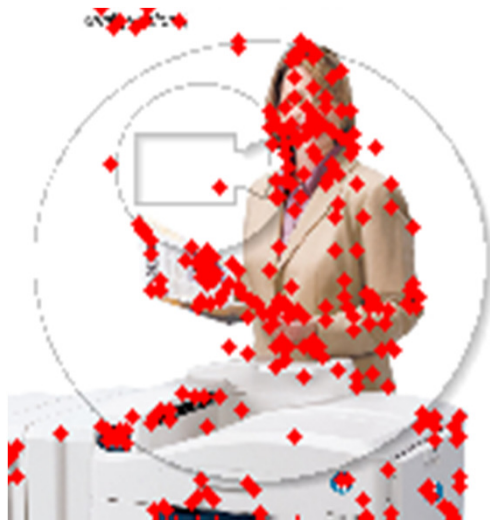
- Where to capture
- How to capture
- What is available
- What to index
- How to improve recognition with limited resources

- Our solution: EMM

Embedded Media Markers (EMM) are optical-filter-like overlaid marks printed on paper documents.

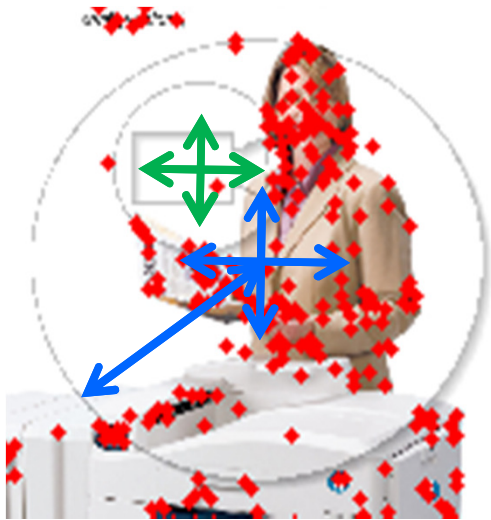
- Provide users multimedia cues and interaction guidance
- Save computation and improve performance
- Minimize the interference with document content

EMM Authoring Tool



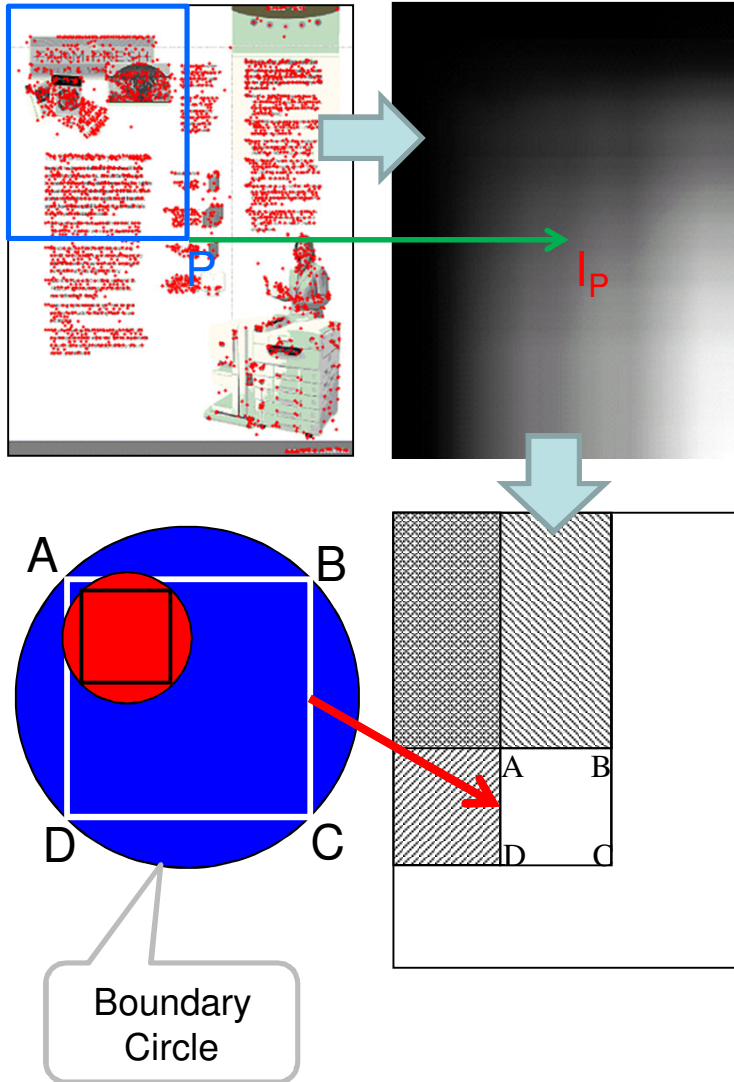
- Semi-automatically arrange EMM based on feature distribution
 - *Criterion 1 – Minimize author's effort. Author only selects an EMM anchor point.*
 - *Criterion 2 – Minimize machine resources used for patch query. Find a small feature boundary, and index the small number of keypoints inside the feature boundary.*
 - *Criterion 3 – Minimize the EMM interference to document. Minimize the number of keypoints overlaid by an EMM.*

Parameter Optimization



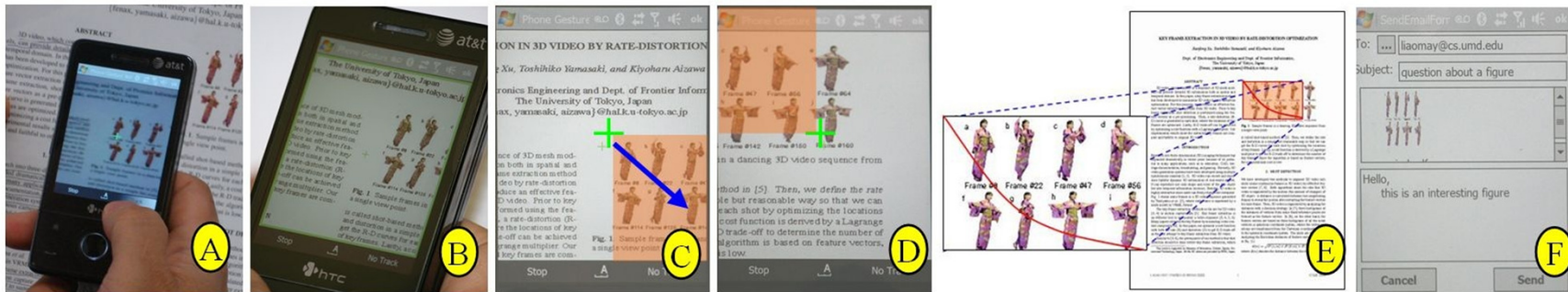
- EMM boundary optimization
 - Find the center (X,Y) and the minimum radius R such that
 - The number of keypoints in the circle exceeds the threshold to ensure patch identification accuracy
 - The user selected anchor point is contained in the boundary
- Media type icon placement
 - Select the media-type-icon center (x,y) so that the icon covers the minimum number of keypoints

Parameter Optimization Speedup FX PAL



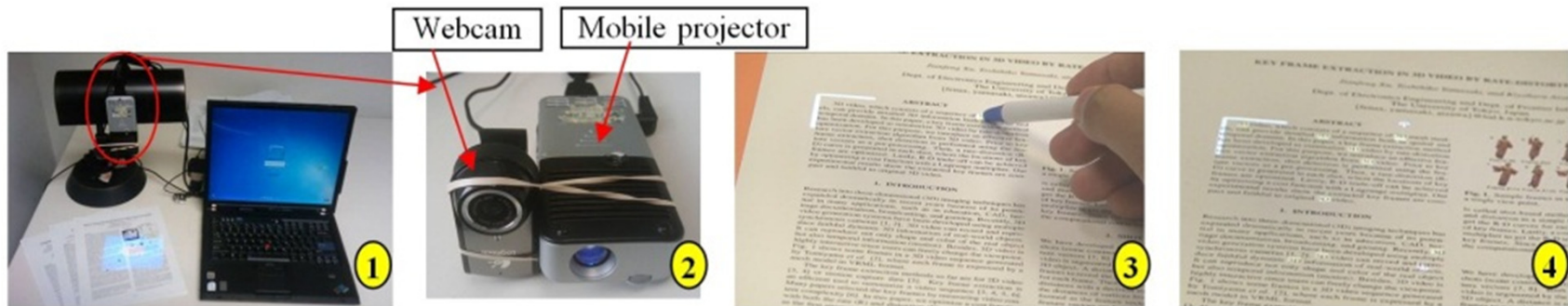
- Counting the number of keypoints in a circle is time consuming
 - $O(2N)$. N is the number of keypoints in a page.
- Speedup
 - *Inscribed square to estimate the number of keypoint in a circle*
 - *Use the cumulative feature-point histogram*
 - $I_{ABCD} = I_C - I_B - I_D + I_A$
- Optimization of media type circle is similar

Fine-grained Phone-paper Interactions



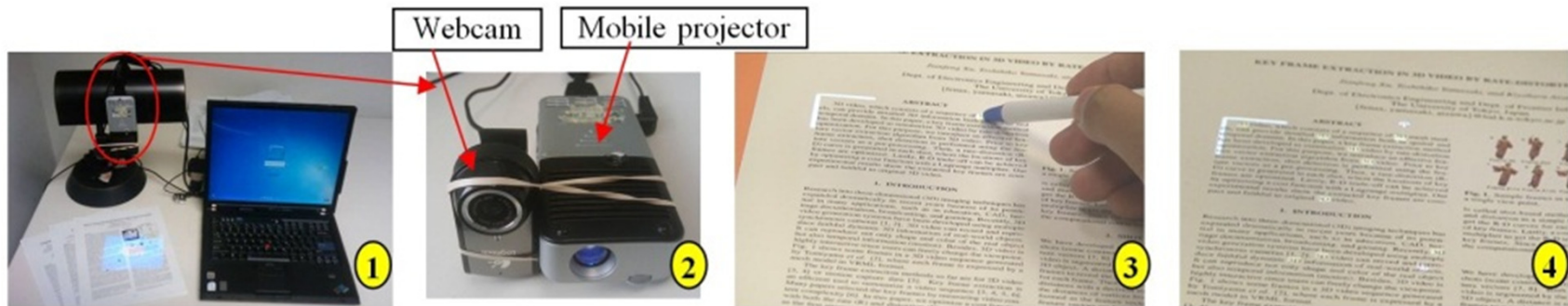
- PACER [Liao and Liu] features a camera-touch hybrid interface. It allows users to manipulate fine-grained document content with various gestures beyond point-and-click.
- [Introduction](#), [Hybrid Gesture](#), [Application](#), [Remote Collaboration](#).

FACT: Fine-grained Cross-media Interaction



- Different from the PACER usage scenario, a user may also want a portable system support for reading with papers on a desk. Less mobile but more comfortable.
- FACT [Liao et al.] allows a user drag a picture on a paper page to a nearby laptop with a finger on paper or type text via the laptop keyboard to annotate an illustration in a printout.
- [Introduction](#), [Application](#).

MixPad



- The PaperUI interface can be used with existing computer interfaces to take both advantages. .
- MixPad [Liao and Liu] allows a user to issue pen gestures on the paper document for selecting fine-grained content and applying various digital functions a traditional computer can issue.
- [MixPad](#).

Thank You

Bio

- Qiong Liu is a senior research scientist at FX (Fuji-Xerox) Palo Alto Laboratory. He has authored and co-authored more than 50 papers and holds more than 40 issued and pending patents in the fields of PaperUI, object/document recognition, IR-camera based vital sign detection, immersive conferencing, signal processing, human-computer interaction, and robotics. His papers were nominated for best paper award 3 times and won best paper award once in ACM conferences. He has a Ph.D. in computer science from the University of Illinois at Urbana-Champaign. He's a member of the ACM and a senior member of the IEEE.