STANFORD HCI GROUP

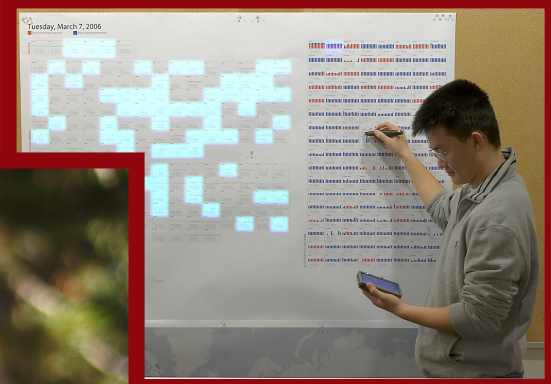
Physical-Digital Ensembles

integrated interactions for capturing, retrieving, and sharing information

Ron B Yeh

23 April 2006

CHI 2006 DOCTORAL CONSORTIUM



Computers Everywhere

Five C.S. challenges for 2006

- Each challenge is for a specific subfield
- Each challenge also applies to *all* of Computer Science

The Computer Science Challenges

Visibility	experimental systems and visualization	See
Complexity	theory, economics, gaming	Know
Abstraction	nanotechnology, parallel systems	Build
Connection	internet, channels	Tie
Invisibility	human factors and user interface	Fit

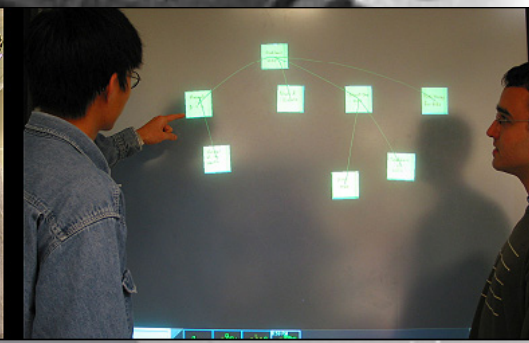
Scenerio 2 "augmented reality"

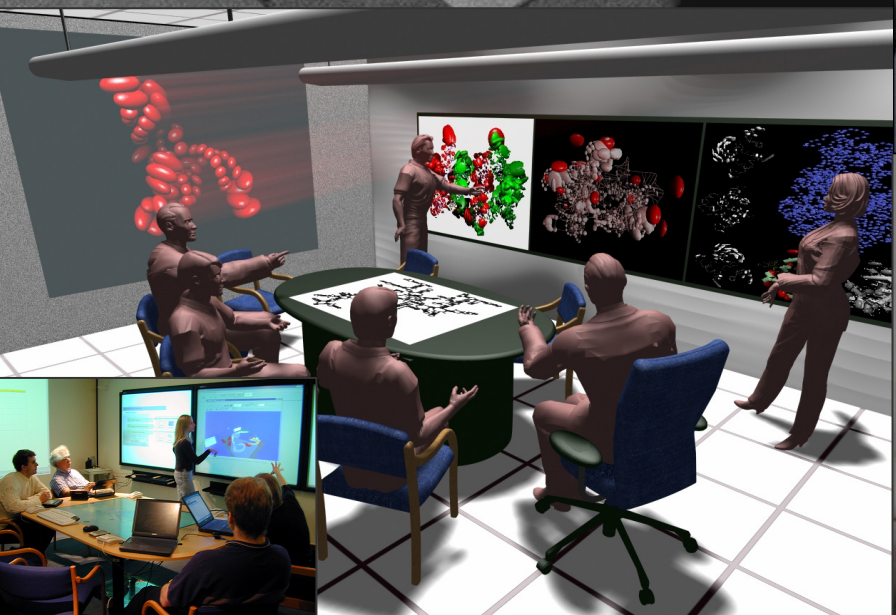
existing physical devices +
cheap and easy-to-use electronic add-ons

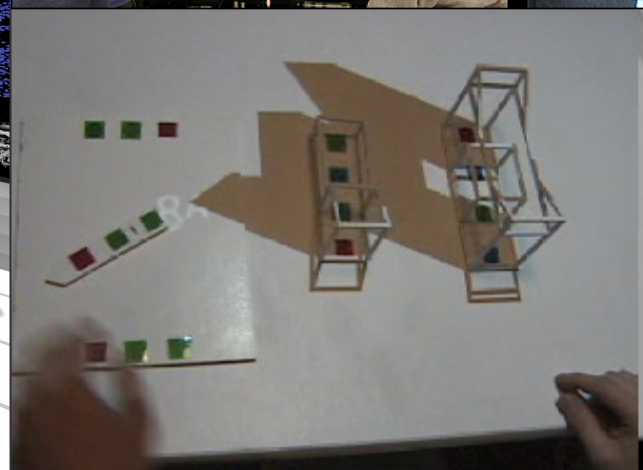
- Wallet + digital cash and digital ID
- Paper Notebook + . . . facts at your fingers
- Automobile + . . . directions and identity
- Kitchen Cabinet + . . . contents tracking

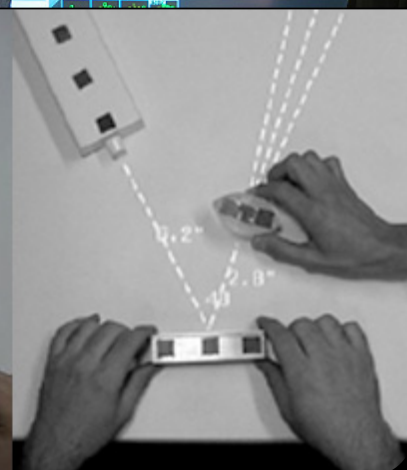
Mark Weiser

Computers Everywhere

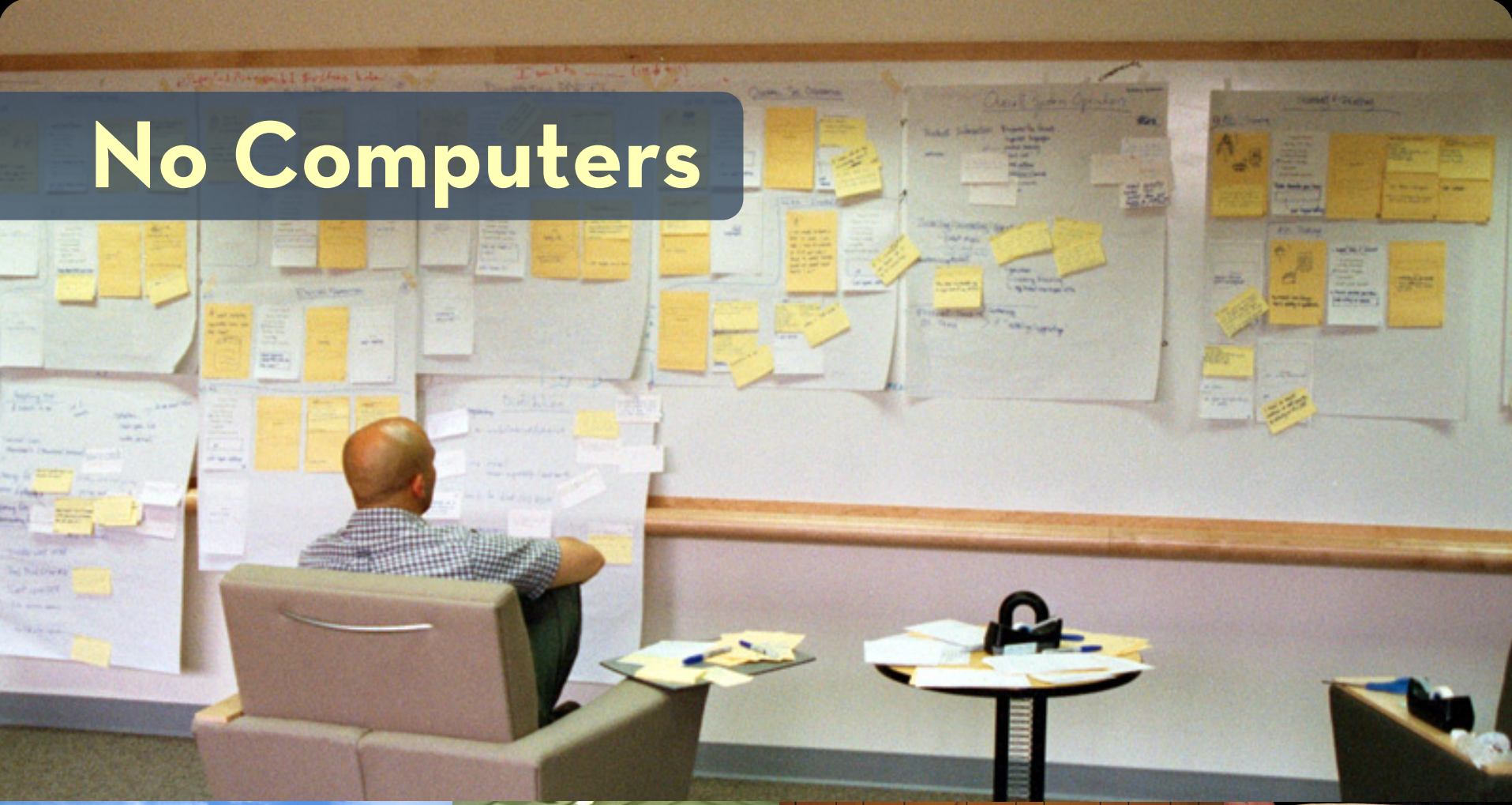


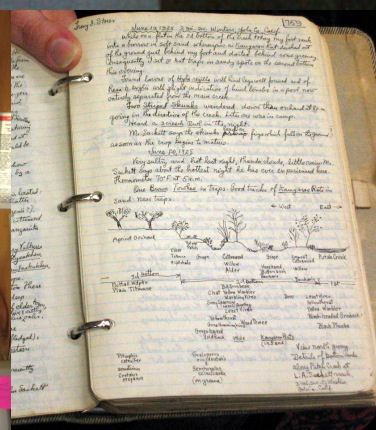






No Computers





Bridging the Physical and the Digital

"...imagine if we did not have to choose, and we had a space where documents could be both paper and electronic at the same time."

Pierre Wellner, 1993

"Choosing between books and computers makes as much sense as choosing between breathing and eating.... the bits and the atoms belong together."

Neil Gershenfeld, 1999

Device Ensembles

"In the future...digital devices will work in concert, like an ensemble of musicians that achieves a total effect greater than the individual performers."

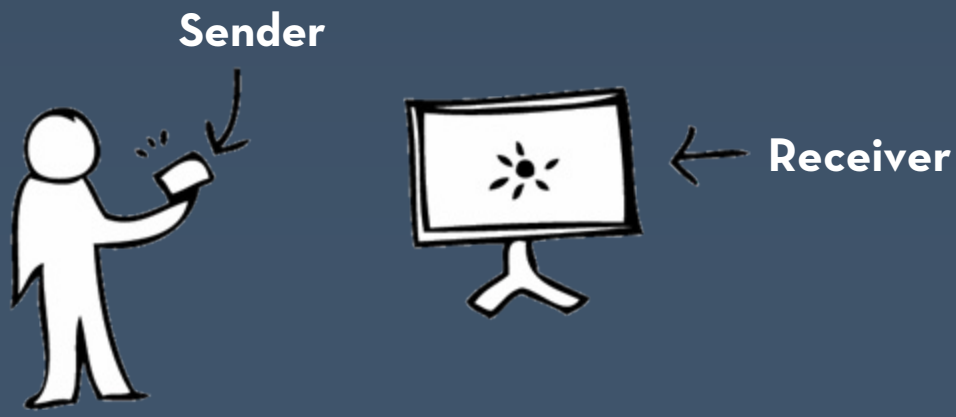
Schilit & Sengupta, 2004

Ensemble Interaction

A **physical-digital ensemble interaction** is a human-computer dialogue that takes place across multiple tools (physical and digital), possibly leveraging multiple input modalities and output media.

Ensemble Interaction

A user employs a **sender** device to initiate an action that is executed on the **receiver** device.



Background

motivation, inspiration, investigation

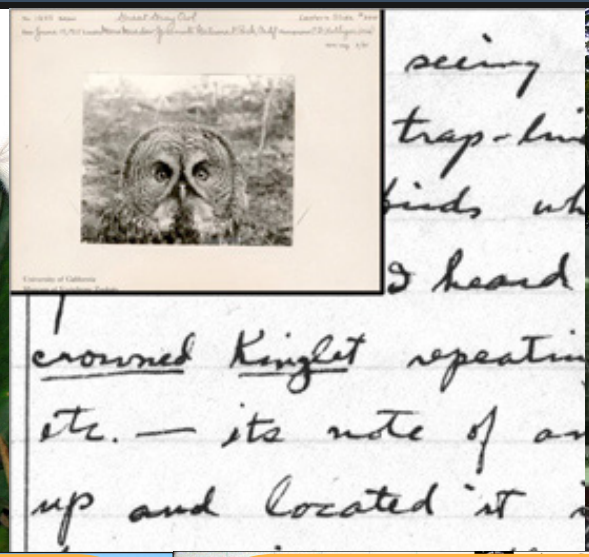
Projects

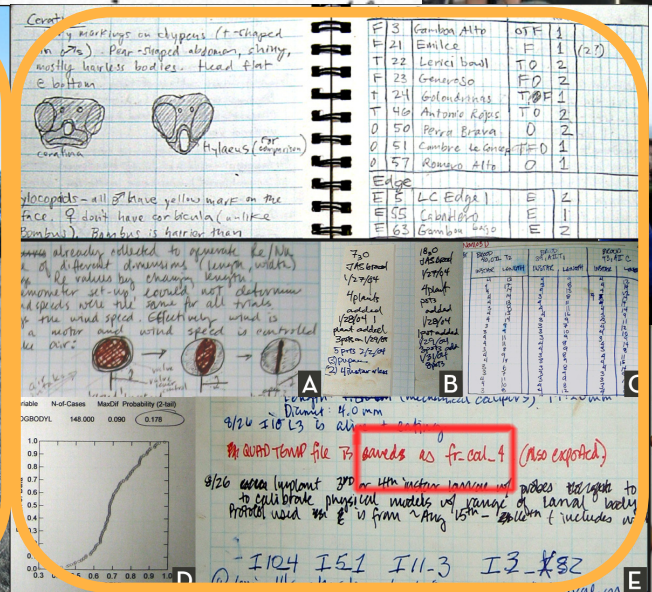
ButterflyNet, Interactive Gigapixel Prints, Sensing Notebook

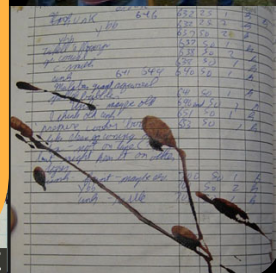
Prior and Future Work

taxonomies, physical-digital primitives, ensembles toolkit

Interviews and Observations







Los Tuxtlas Tropical Rainforest

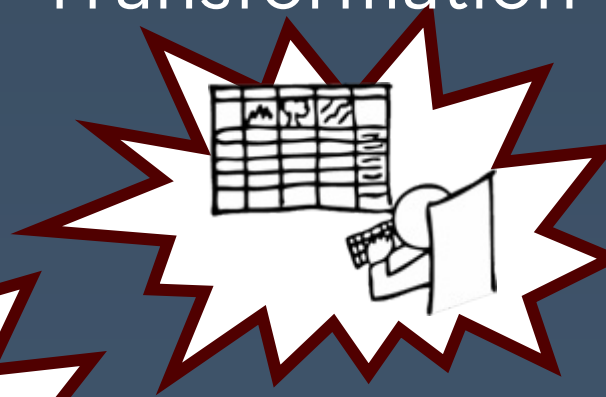
Jasper Ridge Biological Preserve

We observed that...

Capture is (relatively) easy, but...

Access

Transformation



Sharing

...are not.

Current tools

Pens & Paper Notebooks

Cameras

Spreadsheets

Coin Envelopes

Laptop & Desktop Computers

Sensors

GPS Devices

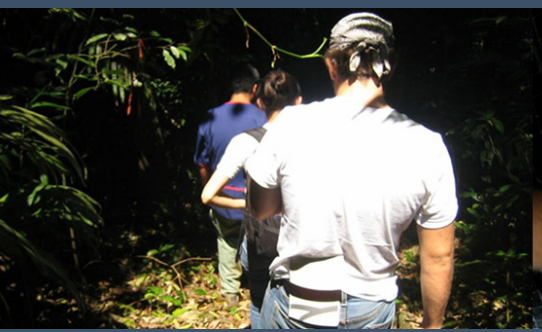
GIS Software

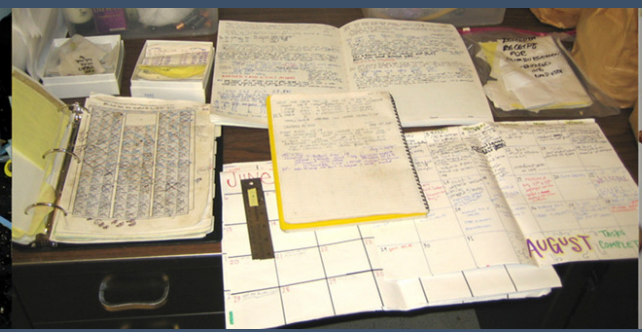
Printers

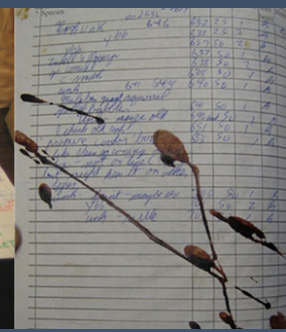
Physical/Tangible	Digital
Pens & Paper Notebooks	
	Cameras
	Spreadsheets
Coin Envelopes	
	Laptop & Desktop Computers
	Sensors
	GPS Devices
	GIS Software
	Printers

Different Advantages

Paper Notebooks [Robust, ∞ “Battery”, …]







Computers [Search, Storage, Sharing, …]

Paper Notebooks

[Robust, ∞ Battery, ...]

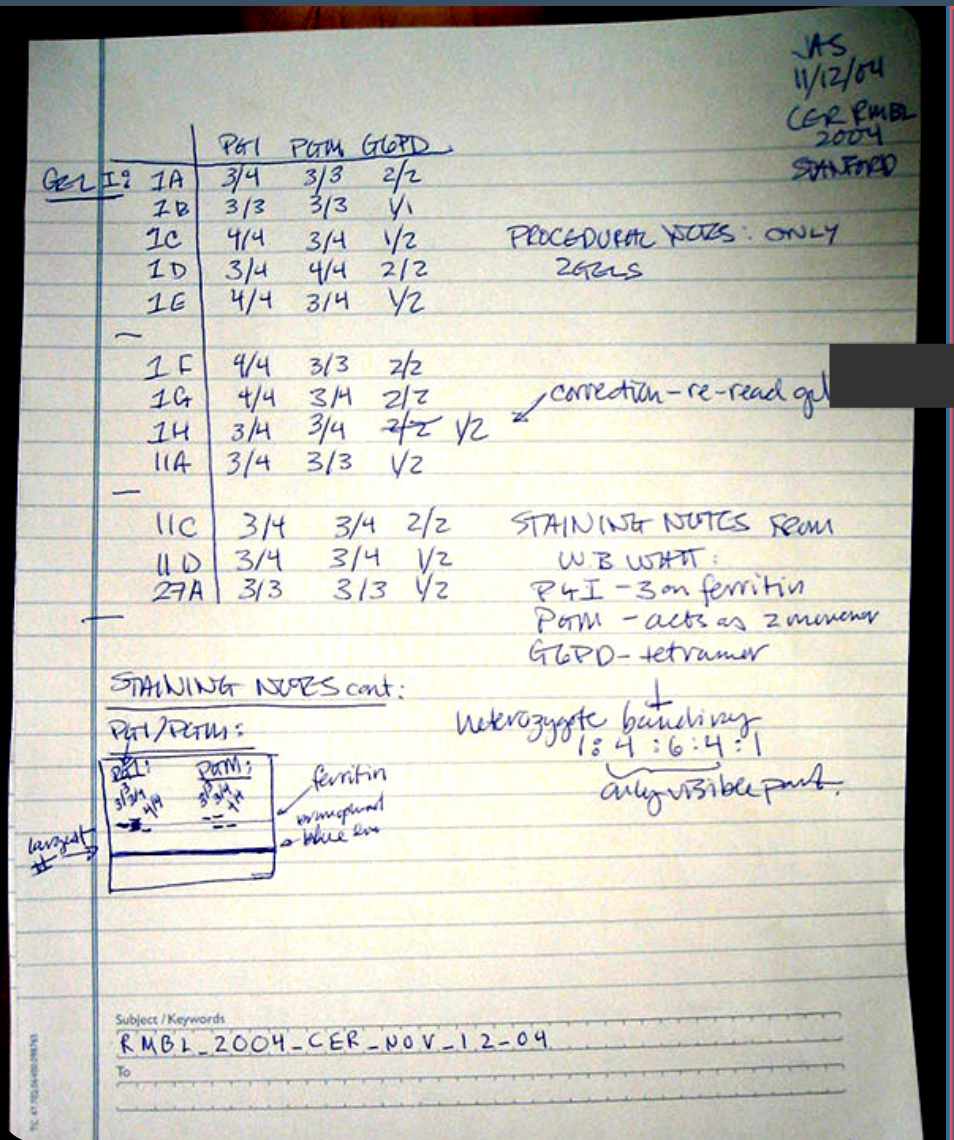
Computers

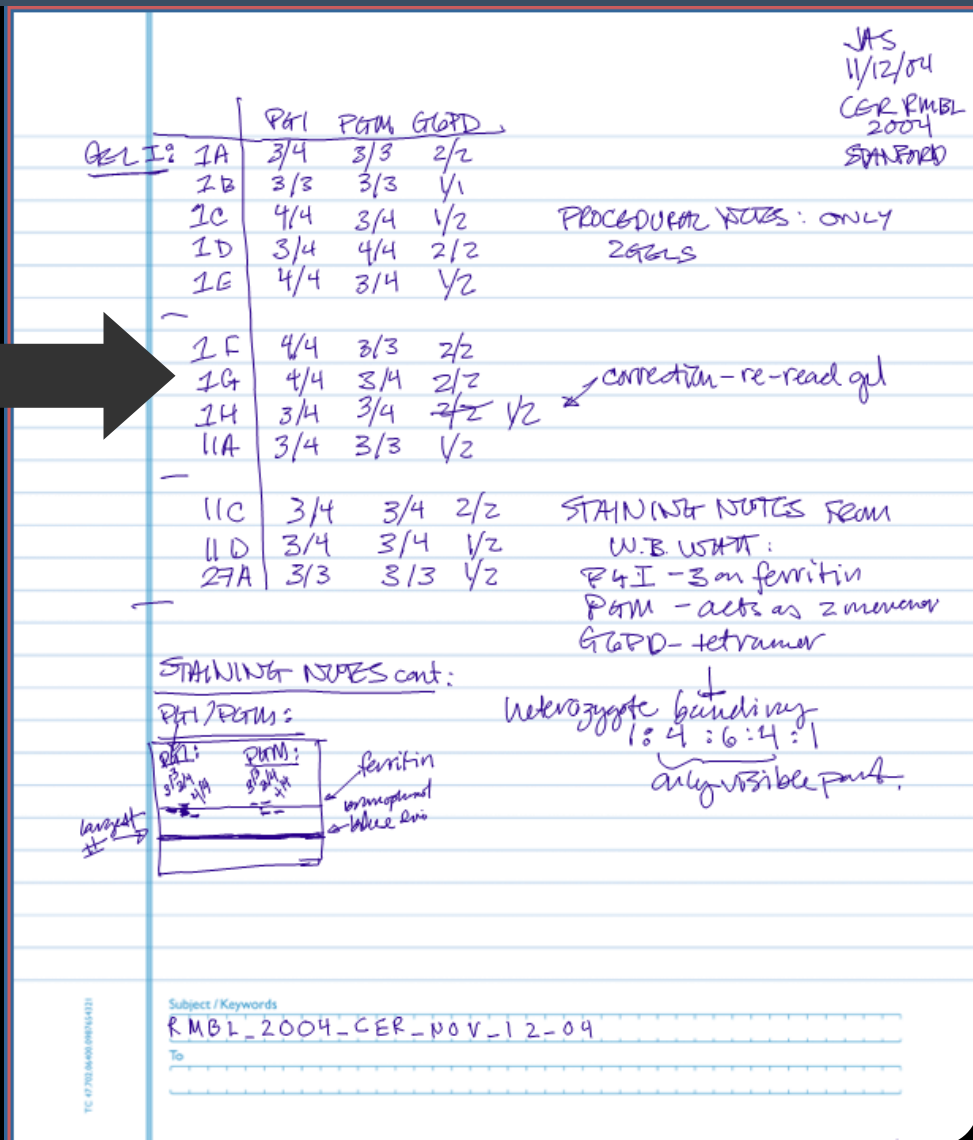
[Search, Storage, Sharing, ...]

1) Augment paper with digital affordances (and vice versa).

2) Use both digital and physical devices in concert.

Digitizing Pen Technology

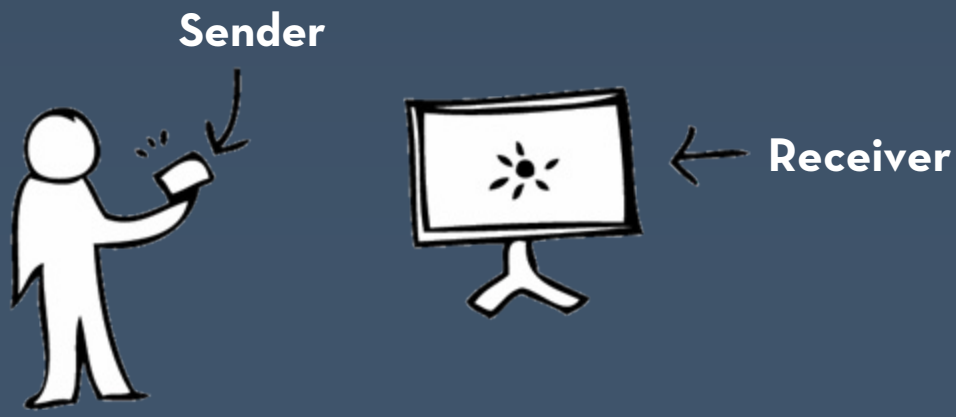




The Ensemble Interactions

Ensemble Interaction

A user employs a **sender** device to initiate an action that is executed on the **receiver** device.



Ensemble Interactions

Select

Manipulate

Associate

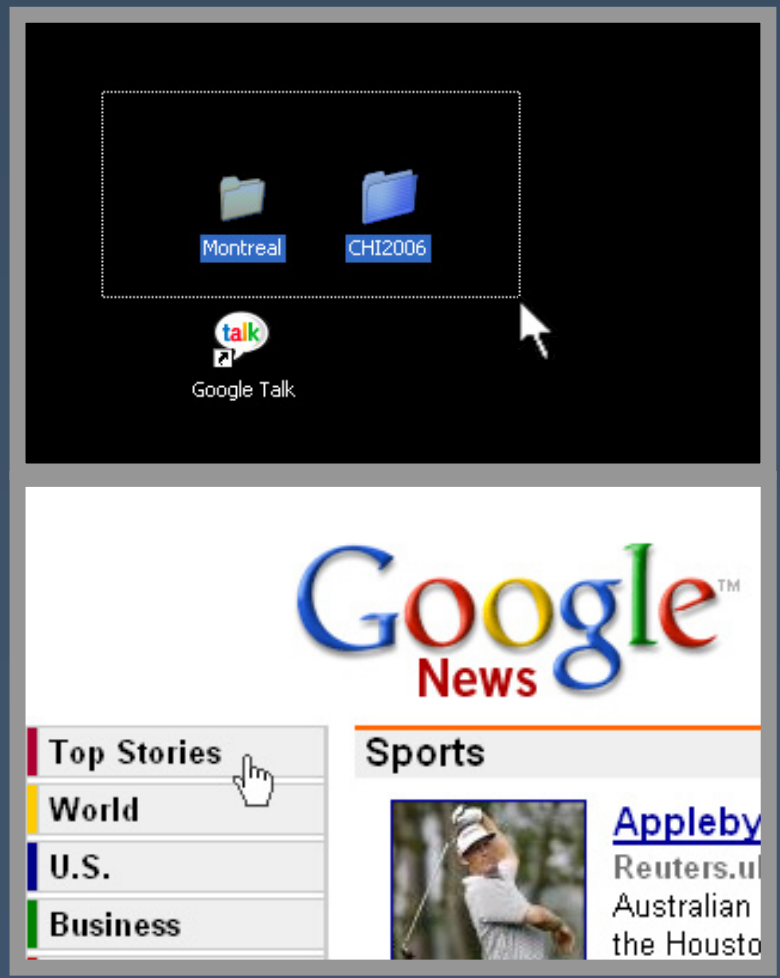
Transport

Select

Graphical UI Select...
[Foley & Wallace 1974]

Ensemble Select

- Subsumes F&W's Pick & Button
- choose item(s)
- constrain movement
- query for results



Manipulate

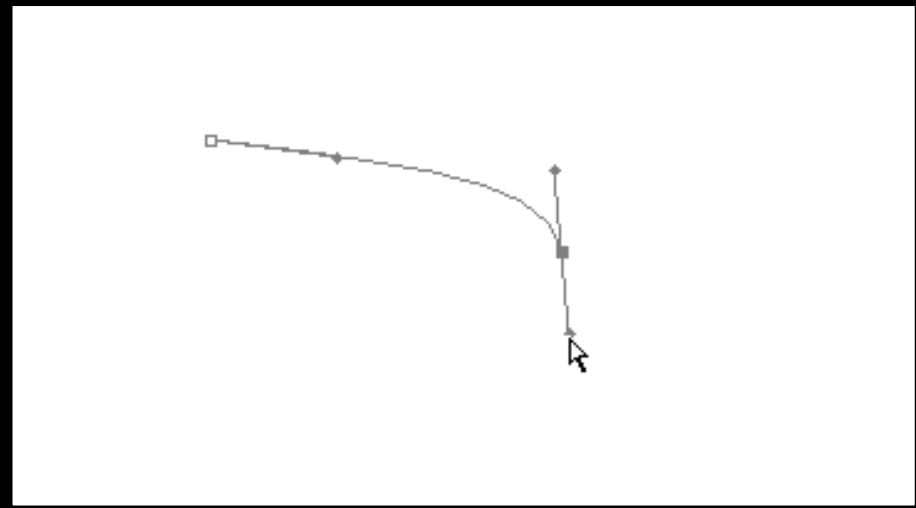
Graphical Manipulate

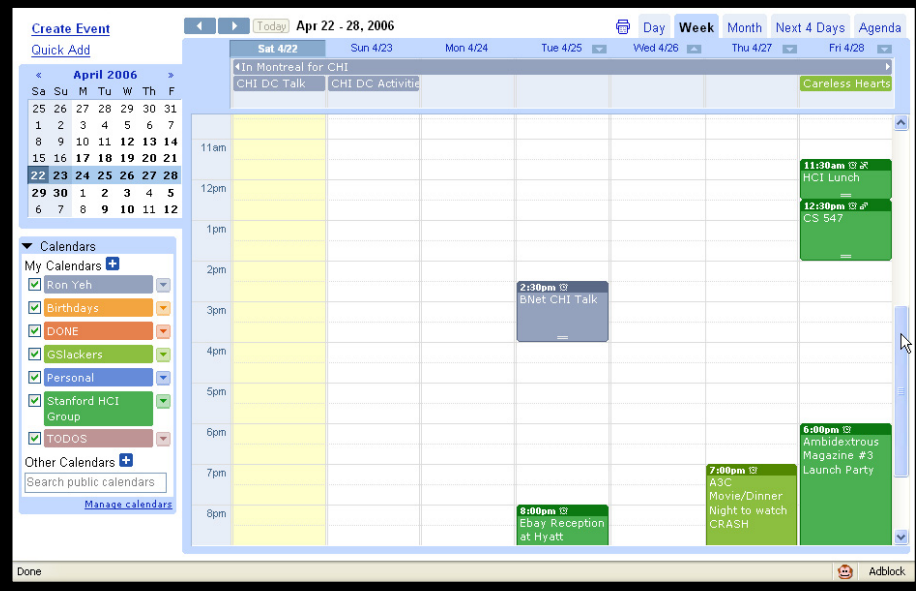
Subsumes F&W's

- Locate
  (Manipulate X,Y,Z,...)
- Valuate
  (Manipulate Values)

Ensemble Manipulate

- Move/Flick/Drag
- Navigate

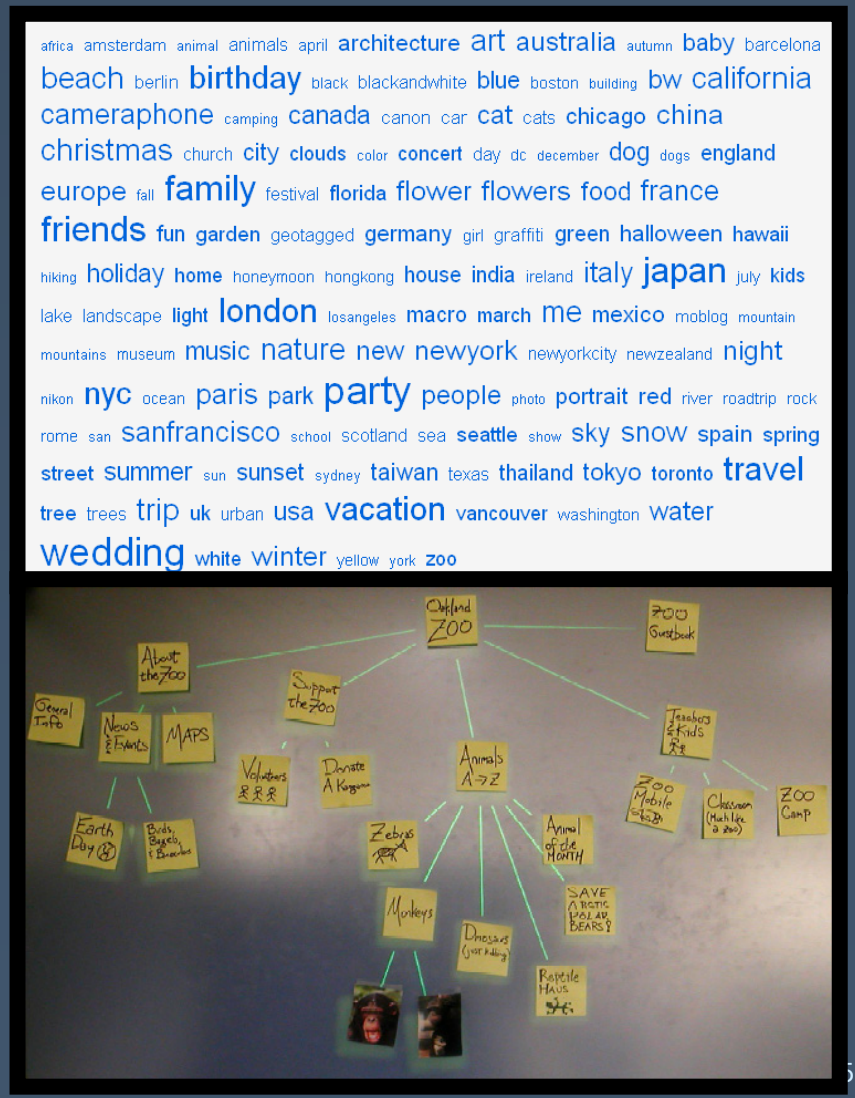




Associate

- Hyperlink
- Stitch
- Connect
- Concatenate
- Attach Behavior

...



Transport

Capture

Print

Send

Retrieve

Copy

Move

...

Background

motivation, inspiration, investigation

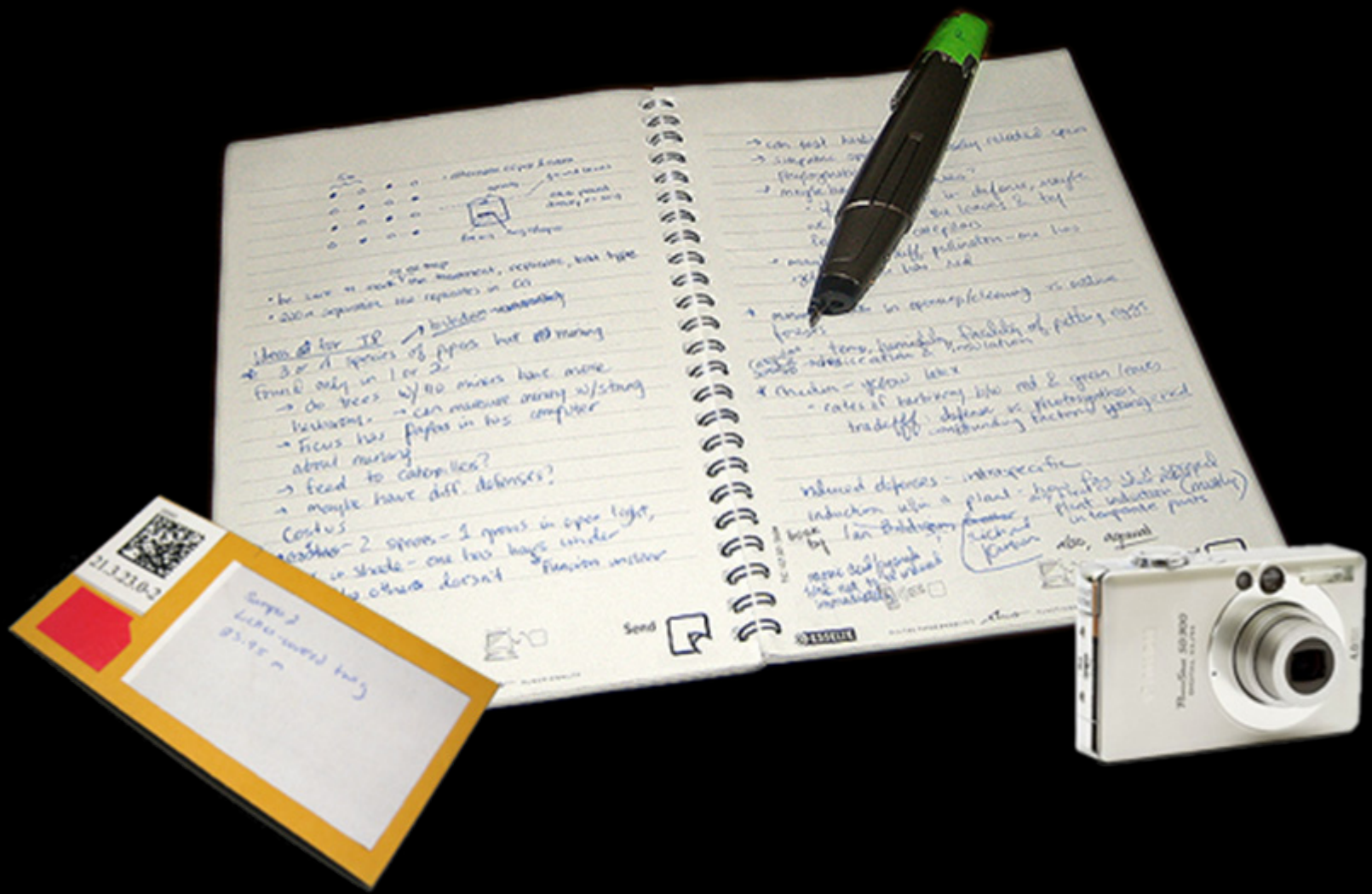
Projects

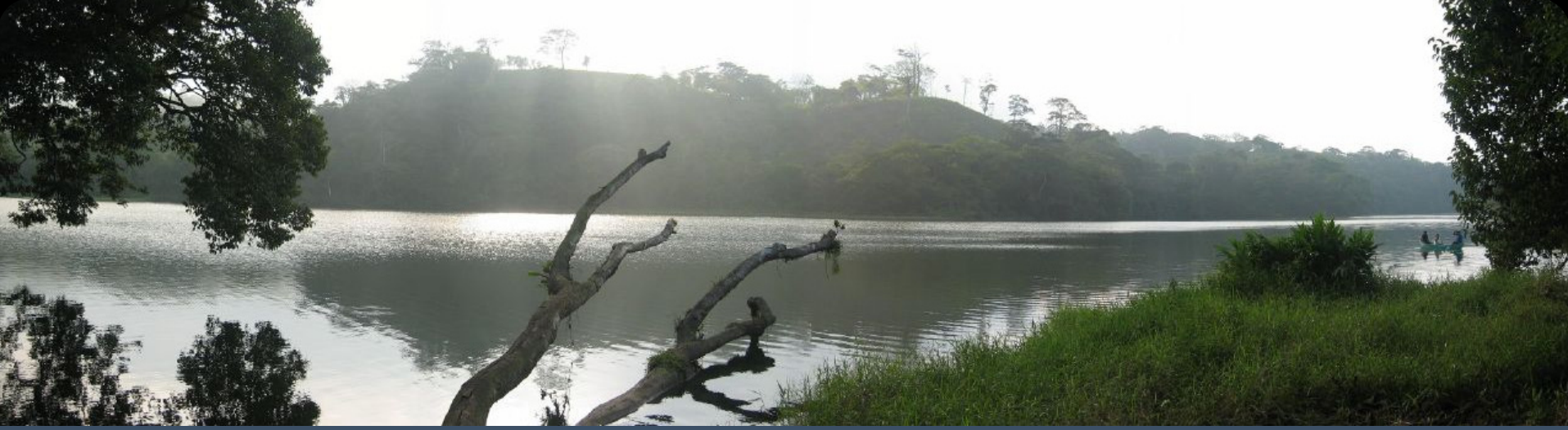
ButterflyNet, Interactive Gigapixel Prints, Sensing Notebook

Prior and Future Work

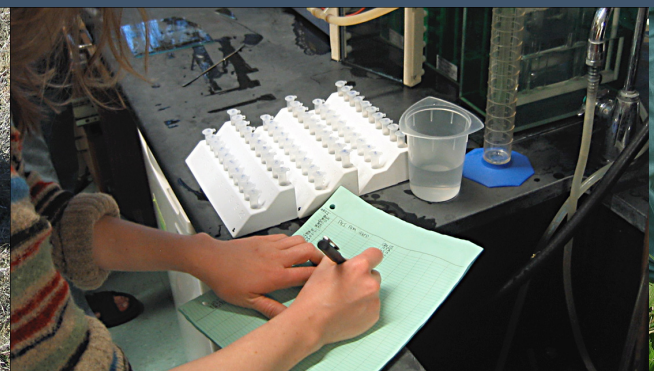
taxonomies, physical-digital primitives, ensembles toolkit

ButterflyNet





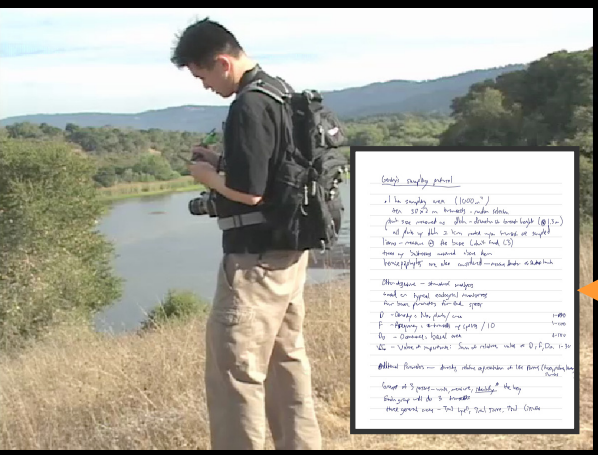
Tools and techniques to help field biologists **collect**, **organize**, and **share** their research content.



ButterflyNet System

Capture Structure Access Transform Share

Ensemble Interaction 1



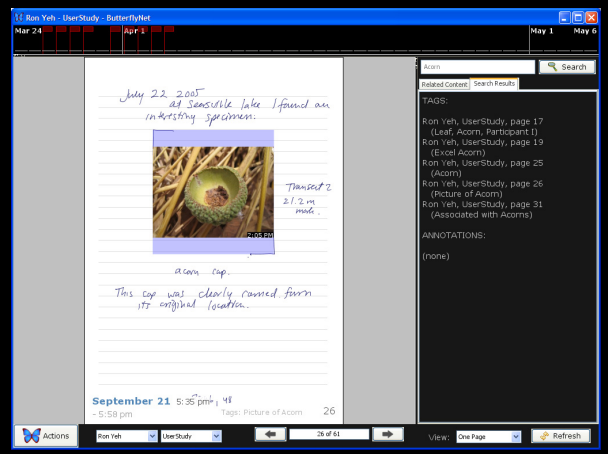
notes @ 4:43pm

photo @ 4:44pm

Automatic Association

Notes + Photos associated by **Time**

Ensemble Interaction 2



Manual "Hotspot" Association

Notes + Photos associated by **Inked Gesture**

Ensemble Interaction 3

Manual “Visual Specimen Tag” Association

Notes + Photos + Specimens associated by **2D BARCODE**

ButterflyNet Browser

Zhen Kan - My Field Notes - ButterflyNet

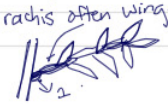
Mar 24 | Apr 1 | May 1 | May 6

araceae anthurium (also araceae dieffenwichia which does not climb)
- vines - herbacious, (vs. lianus, which climbs but has woody
- striking variation in leaf morphology w/in an indiv.
- pollinated by beetles

piper aduncum
- V. light-demanding piper
- strong spicy smell, used for cooking
- striking inflorescence

araceae monstera
- germinate on forest flour, stick itself to (trunk) something will have enough energy to find & -> & eventually reach light
  - invented skoto tropism - directs plant to source of darkness i.e. trunk that's already established in forest
  - capture runoff nutrients that come down the tree
  - will change its morphology to reach more light

leguminosae - ingaceae -> has compound leaves (only 1 bud)
- family is common tree in top rainforests
- rachis often winged



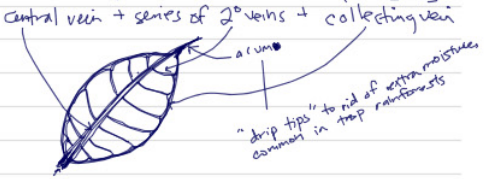
March 20, 2005 1:53 pm
- March 21, 2005 5:11 pm No tags 3

- a gland that acts as a extrafloral nectary - produces nectar separate from the flowers
  - distinguishing feature of an inga
  - -> mutualism w/ants which defends the leaves
- young leaves a lot more hairy than old leaves

cordia
- wood is v. high quality
- leaves in layers

burseraceae bursera - dioecious
- bark peels off (its reddish) - exfoliating bark to expose a green stem

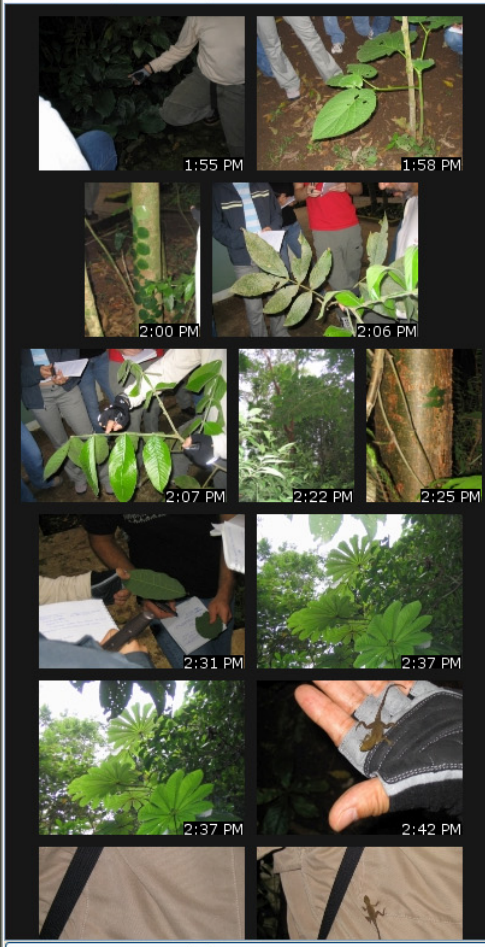
moraceae family - widespread
- white latex (in the stem) - maybe for defense?
- distinctive vein pattern



March 20, 2005 2:09 pm
- March 21, 2005 5:12 pm No tags 4

Search | Search

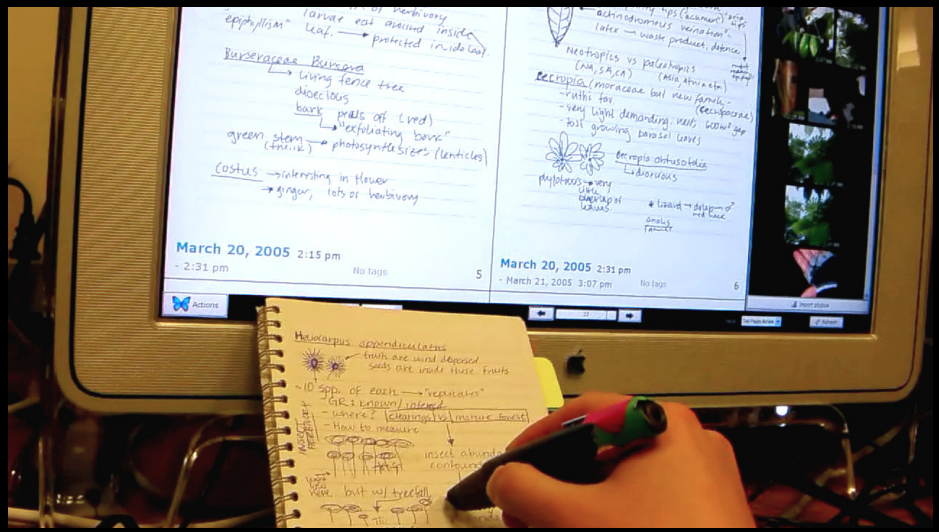
Related Content | Search Results

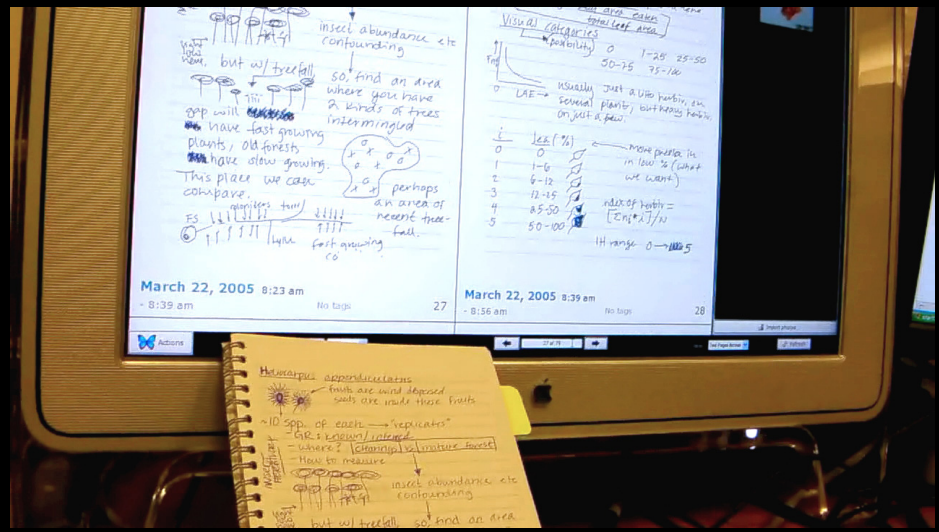


Import photos

Actions | Zhen Kan | My Field Notes | 3 of 94 | View: Two Pages Across | Refresh

Ensemble Interaction 4



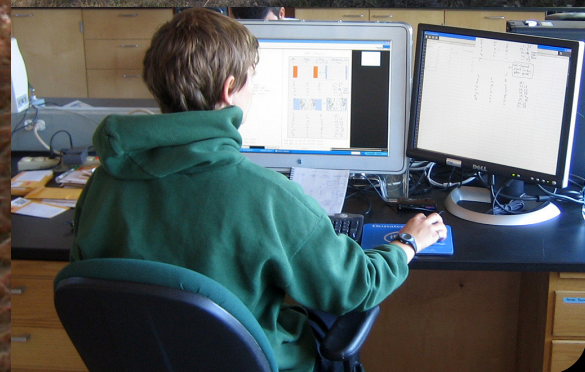


Navigate by Pen & Paper Notebook

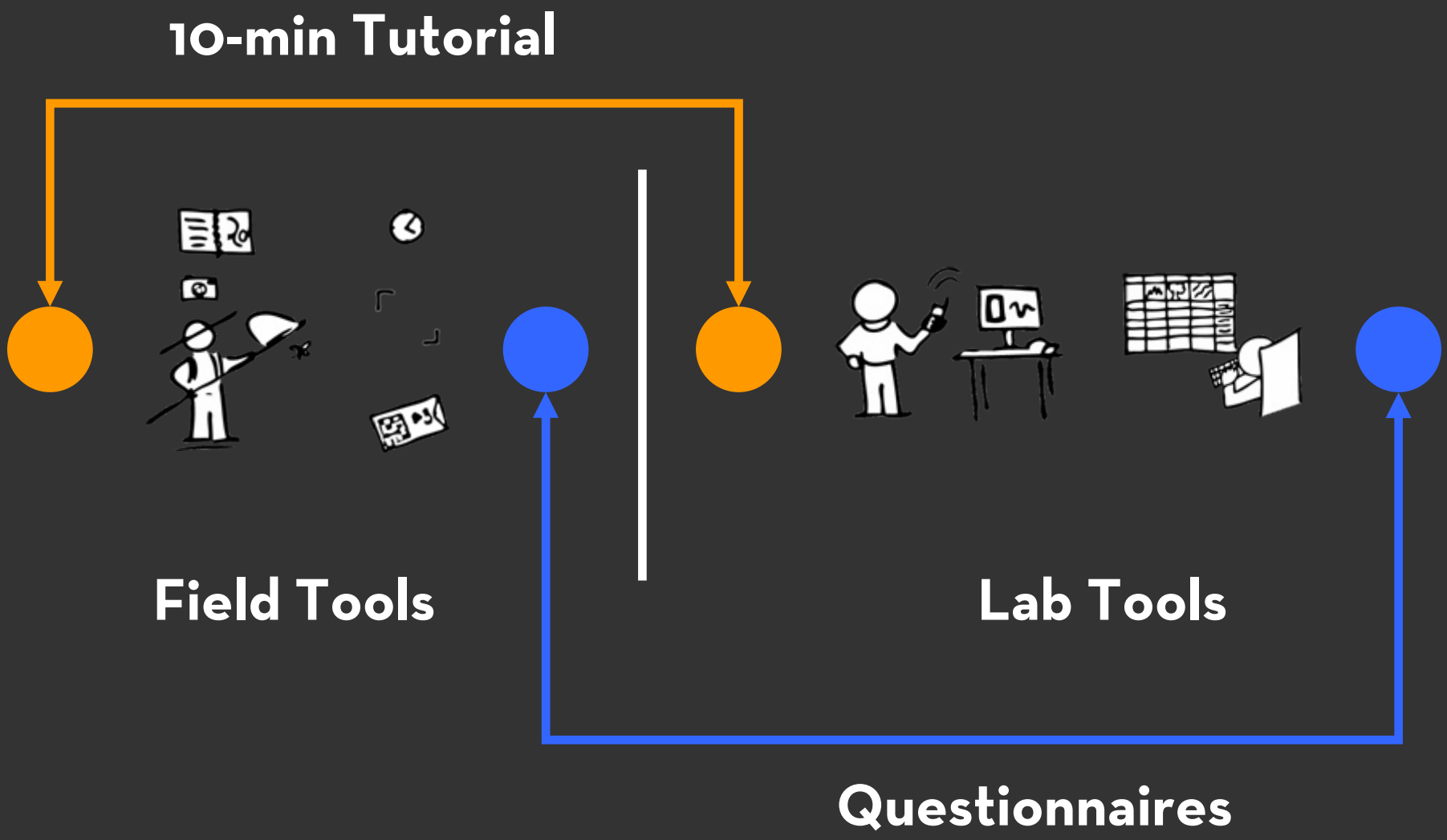
A First-Use Study

14 Field Biologists

2.5-hours each



Experimental Design

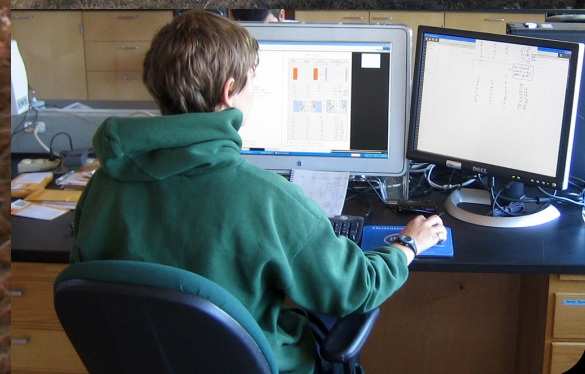


Likes

Automatic C Capture and C lation

Dislikes

Bulky Pen,  adds to field time



Requests

Handwriting Recognition

GPS Integration

Support for audio & other content types

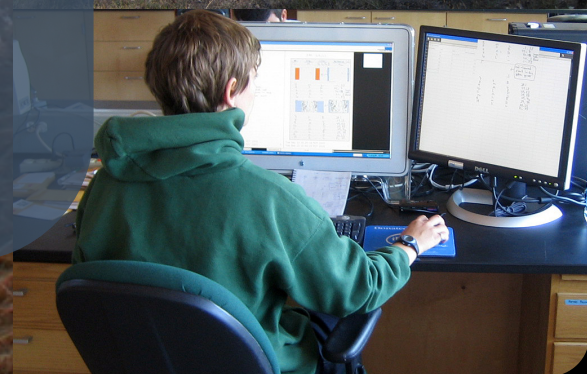
Longitudinal Evaluation

Used By:

- Field Biologists at JRBP/Stanford
- Anthropologists at Intel Digital Home Group

Will Soon Be Used By:

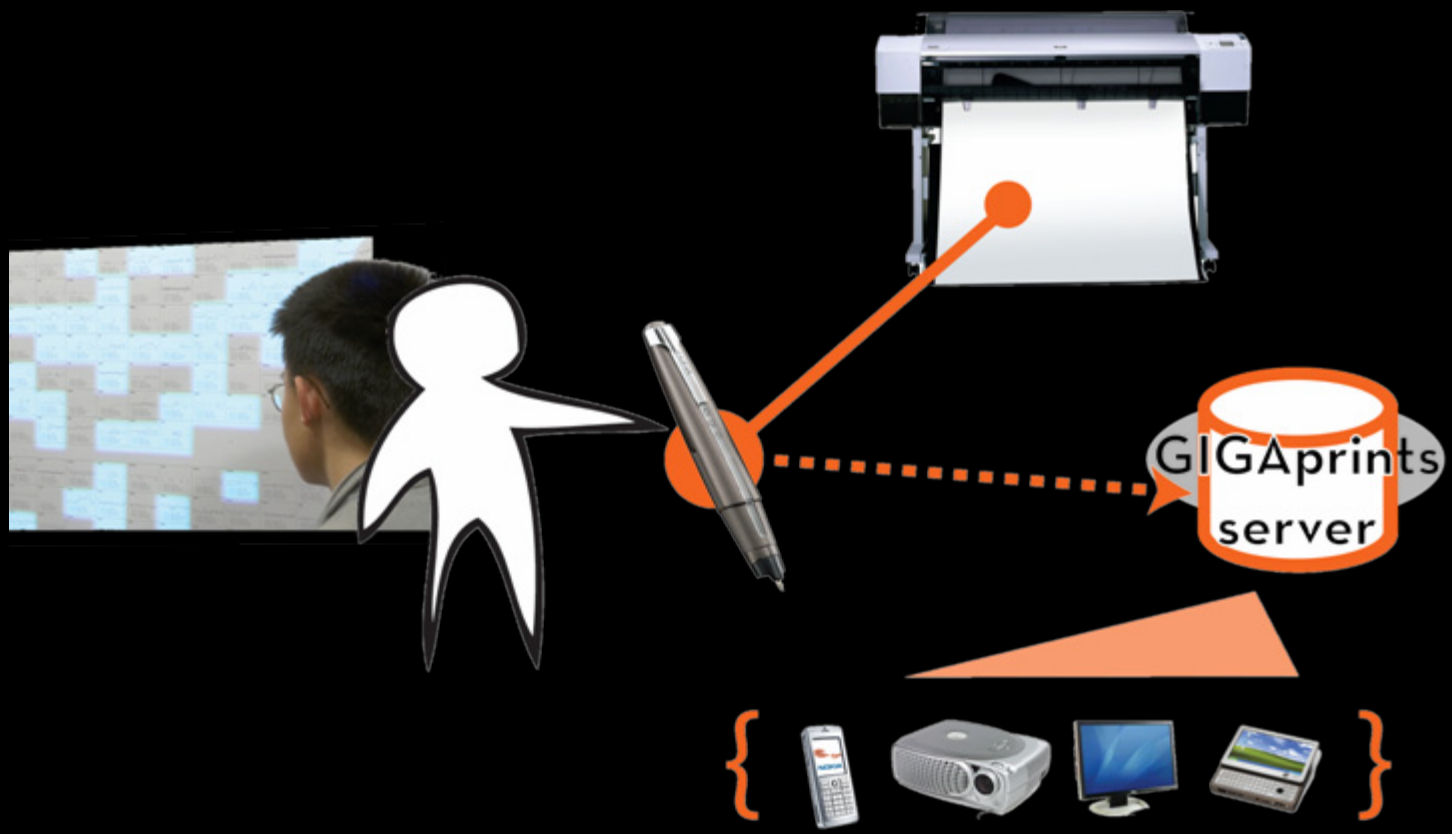
- Cancer Researchers at Stanford
- NASA Researchers
- and more...



ButterflyNet contribution

Leverages ensemble interactions to provide **rich browsing** of notes with automatically and manually associated research content

GIGAprints

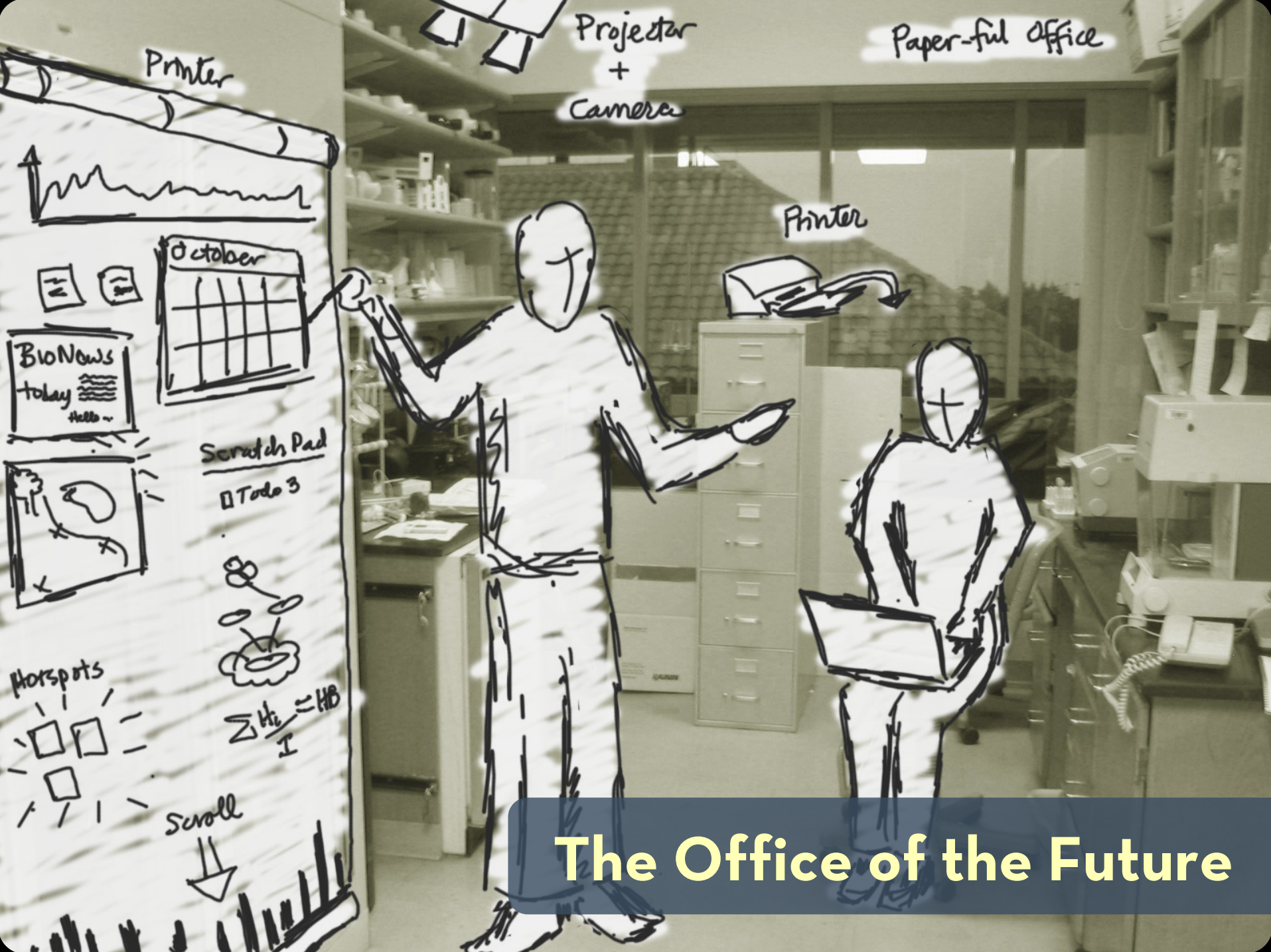


Mission Statement

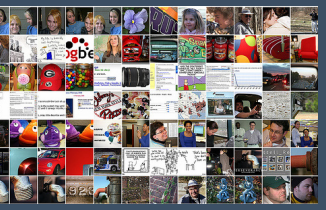
Design and Develop…

1) visualizations for large, paper-based displays

2) techniques for interacting with them.


Printer
Projector
+
Camera
Paper-ful Office
Printer
October
BioNews
today
Hello ~
Scratch Pad
Todo 3
Hotspots
Scroll
The Office of the Future

Paper + Digital Affordances!



Intermittent Output

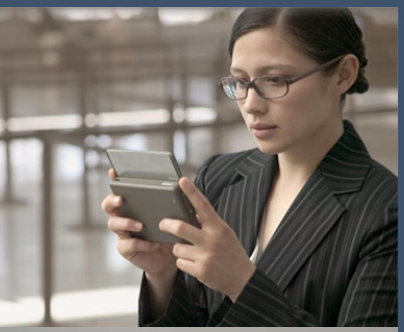
- Print a Visualization on a Wide-format Printer

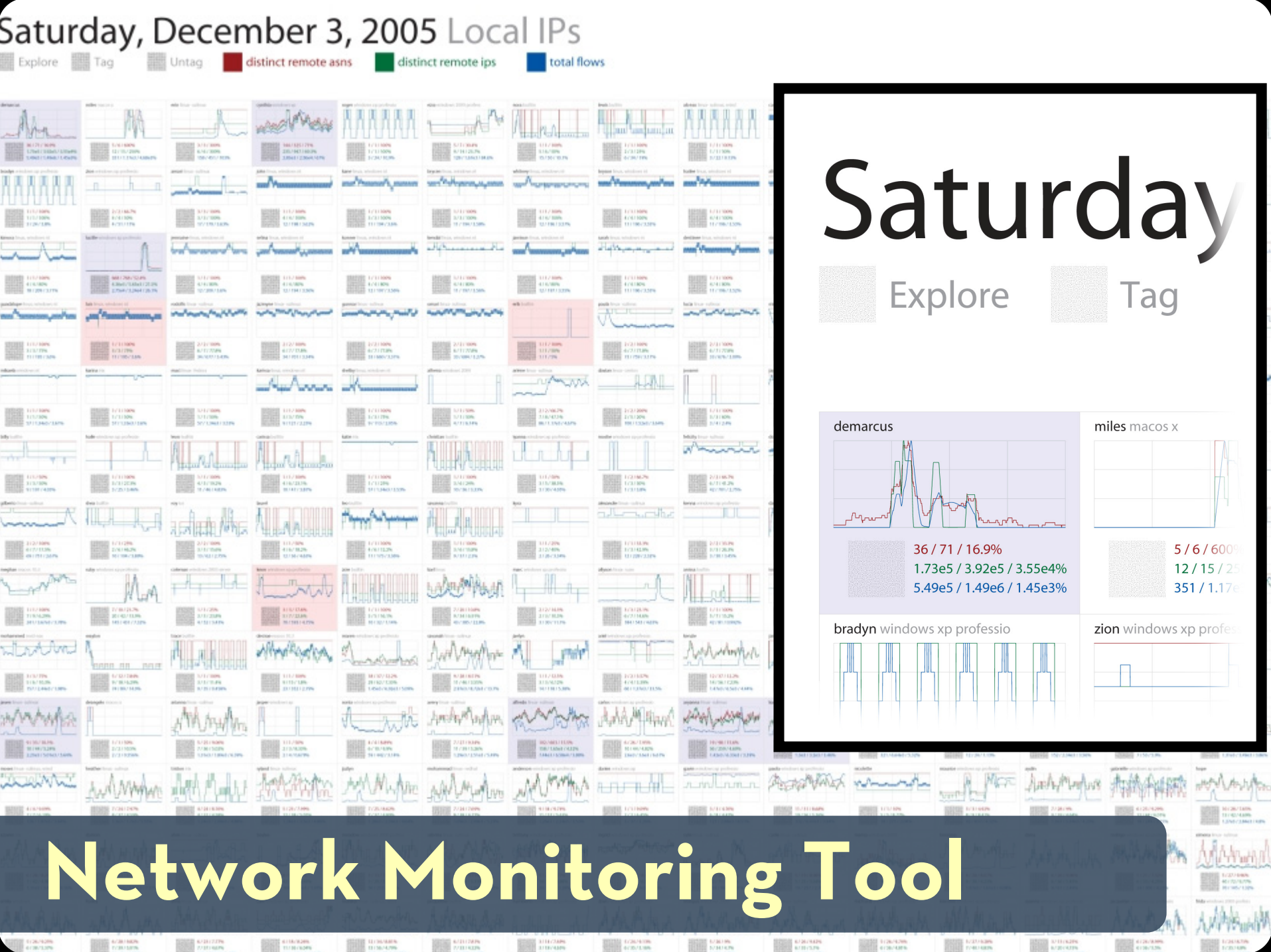
Input

- Digital Pen Technology

Real-Time Output

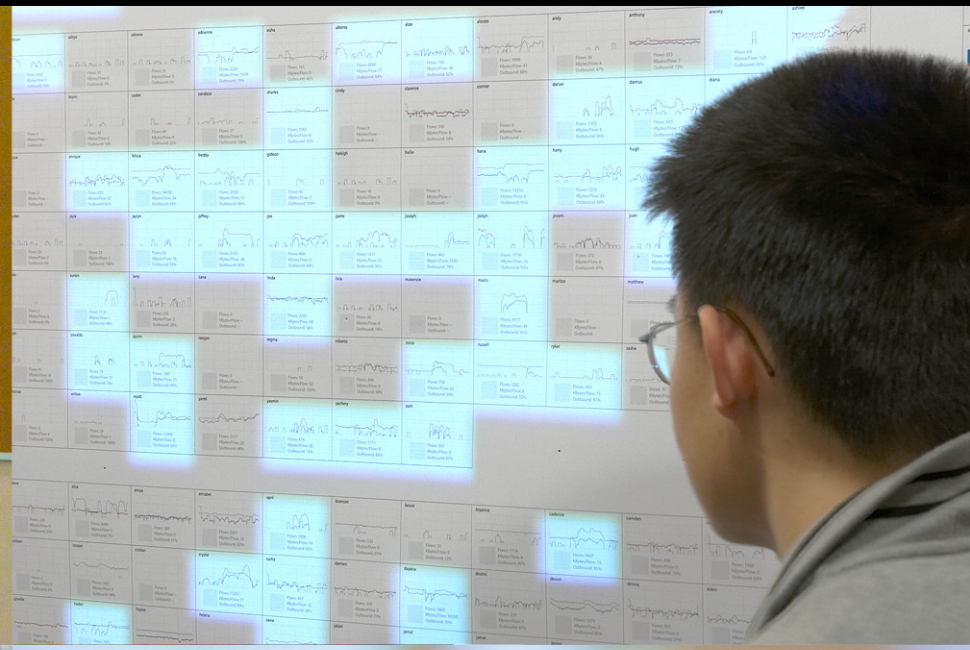
- Mobile Device
- Nearby Display (LCD or Laptop)
- Projected Overlay

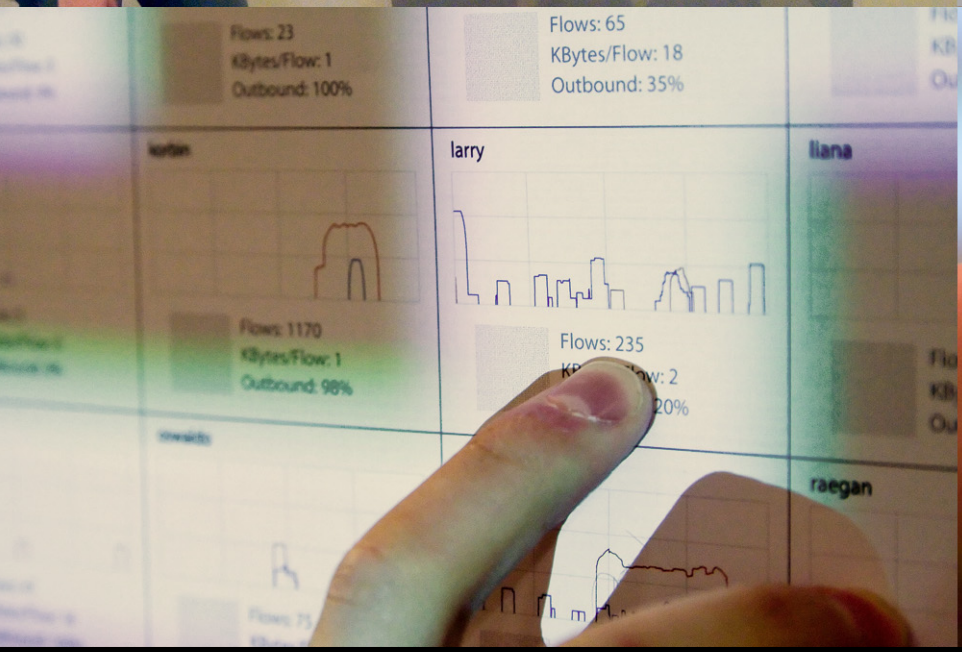


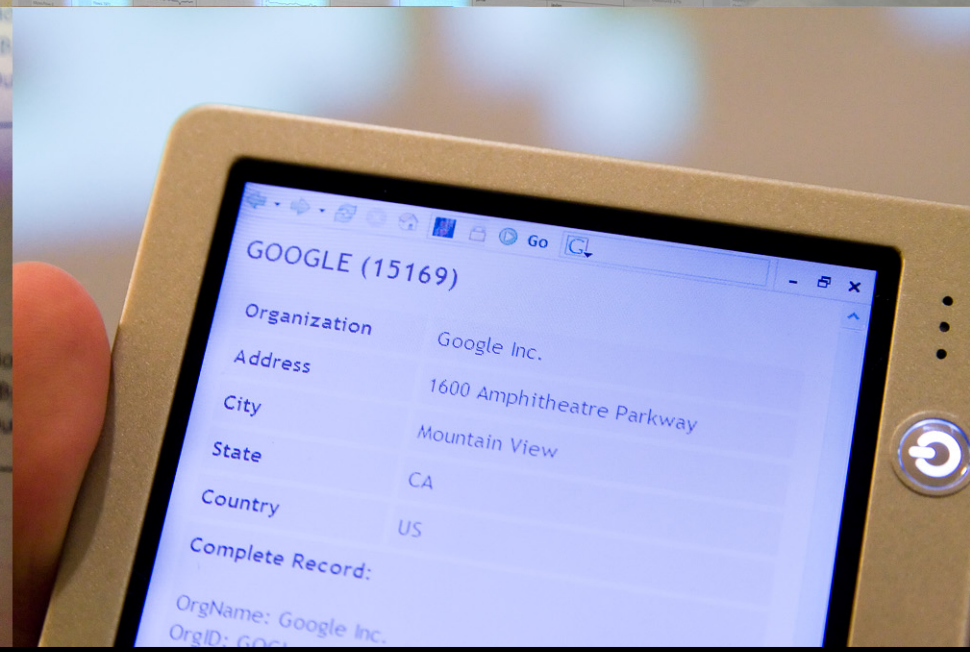


Network Monitoring Tool


Tuesday, March 7, 2006




Flows: 23
KBytes/Flow: 1
Outbound: 100%
Flows: 65
KBytes/Flow: 18
Outbound: 35%
larry
liana
Flows: 1170
KBytes/Flow: 1
Outbound: 98%
Flows: 235
raegan


Go
GOOGLE (15169)
Organization
Google Inc.
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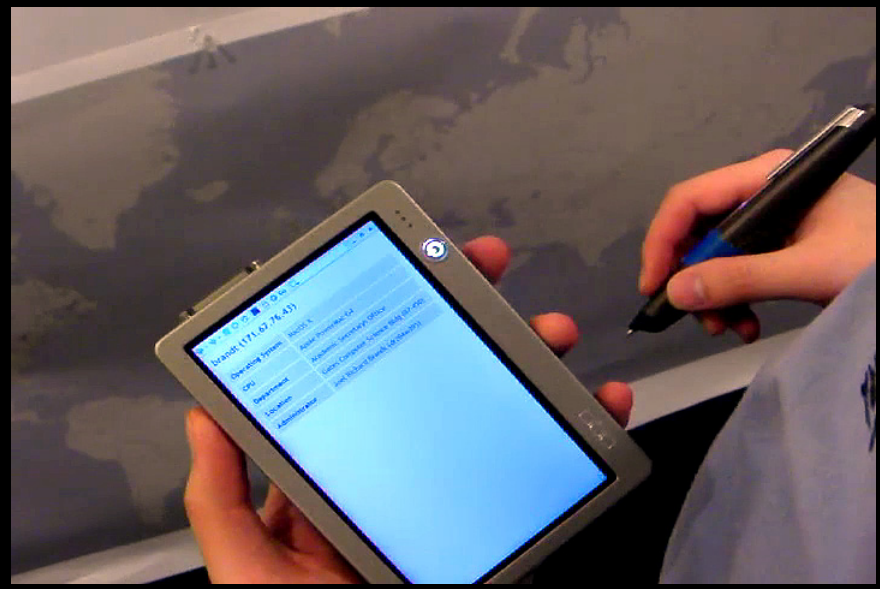
1600 Amphitheatre Parkway
City
Mountain View
State
CA
Country
US
Complete Record:
OrgName: Google Inc.

Ensemble Interaction 5

Transport



Progressive Information Disclosure

Ensemble Interaction 6

Photo Browsing and Tagging

Ensemble Interaction 7

Architect Navigates a 3D View for Client

GIGAprints contribution

Augment large paper surfaces with digital content (on mobile device, projector…), to provide **visual context, collaboration**, and **mobility**.

The Sensing Notebook

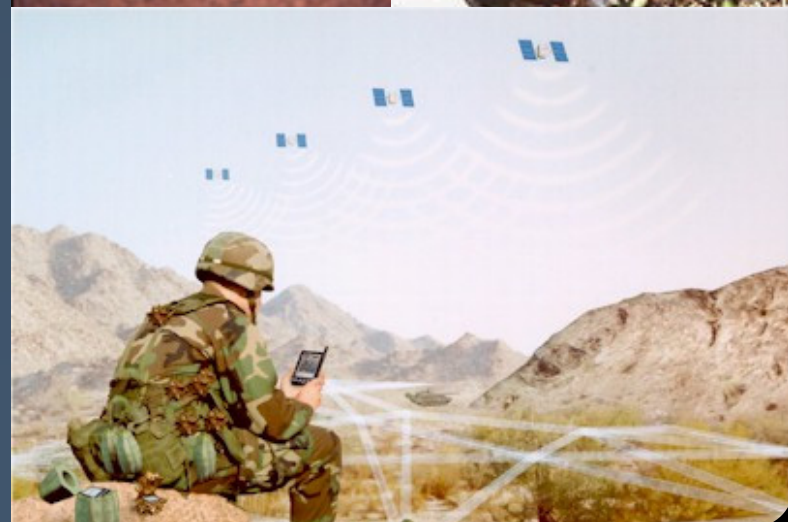
Configure and Manipulate Sensor Networks

Field Sciences

Industrial Monitoring

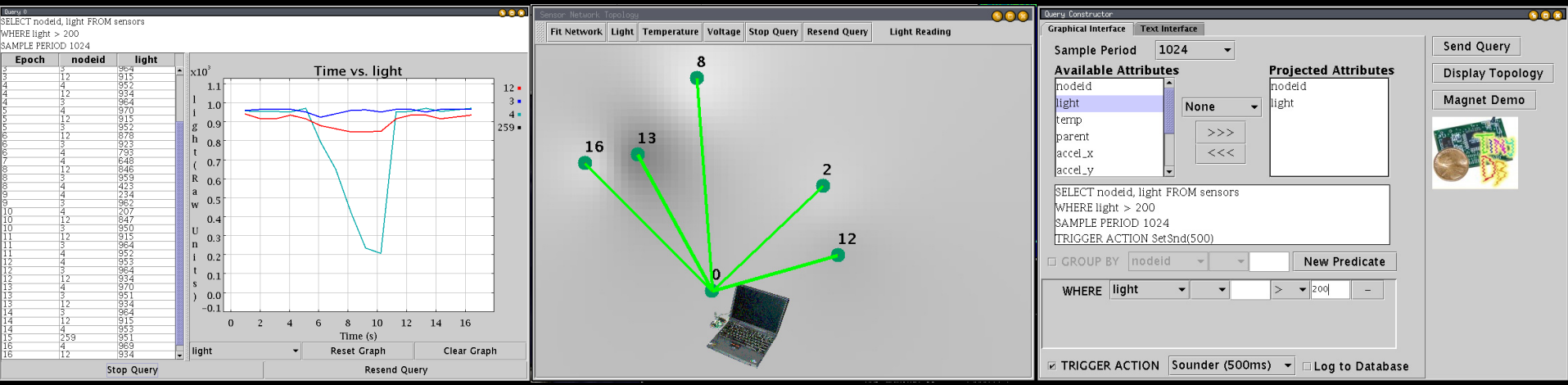
Digital Home

...and more



Photos from
[Crossbow, USC, VATech, UCLA]

A Desktop Interface (Tiny DB)



A Programmer's Interface (Maté)

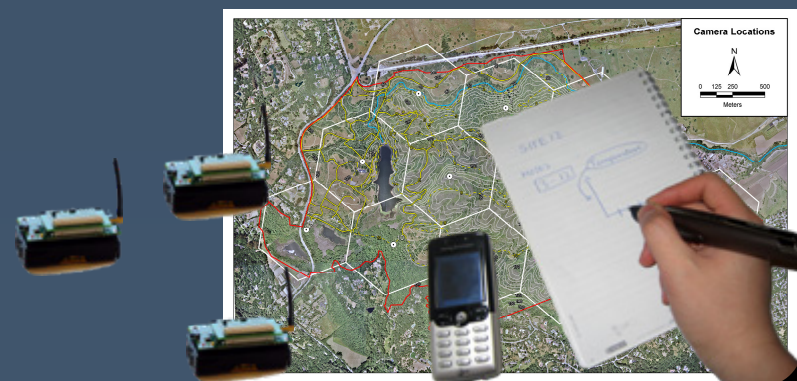
```
buffer data;
data[0] = light();
send(data);          ! Route the data to a collection point
```

Our Goal

Provide a **learnable** yet **efficient** interface for configuring and querying sensor networks.

As these wireless sensors tend to be deployed outside, use an ensemble of a mobile device (*e.g.*, phone) and a portable paper surface (*e.g.*, notebook) to communicate with the sensors.

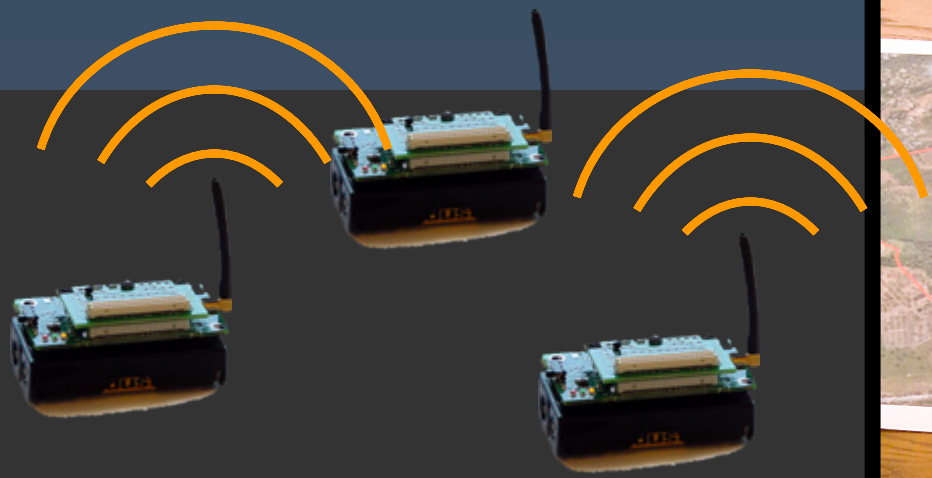
This is work-in-progress! ☺



Ensemble Interaction 8

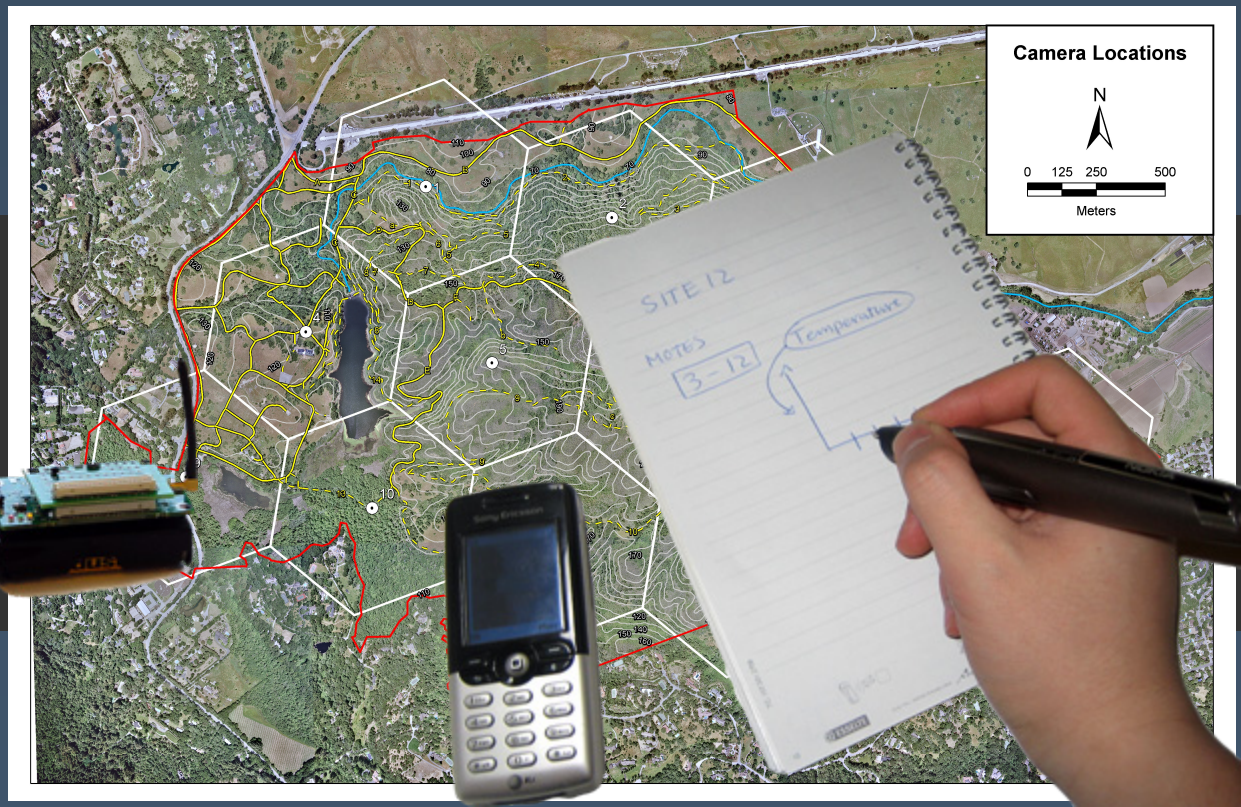
Select

Transport



Select and Transport Live Field Data

Ensemble Interaction 9



Configure Sensor Networks via Gestures

Background

motivation, inspiration, investigation

Projects

ButterflyNet, Interactive Gigapixel Prints, Sensing Notebook

Prior and Future Work

taxonomies, physical-digital primitives, ensembles toolkit

Graphical User Interface Primitives

[Foley and Wallace 1974]

- Pick
- Button
- Locator
- Valuator

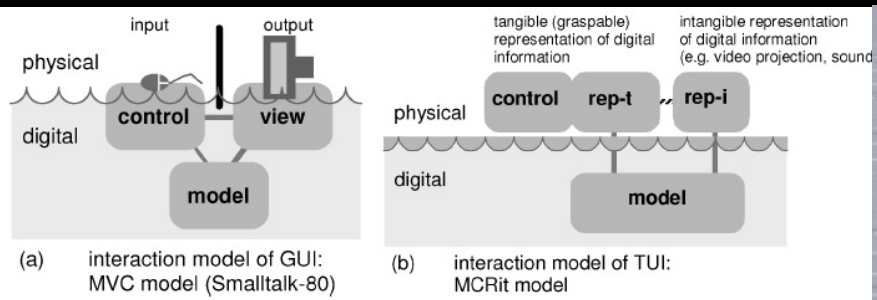
[Myers 1990]

- Menu
- Move-grow
- New-point
- Angle
- Text
- Trace

Tangible User Interfaces

Framework from Ullmer, Ishii, and Jacobs
MCRit (MCRpd)

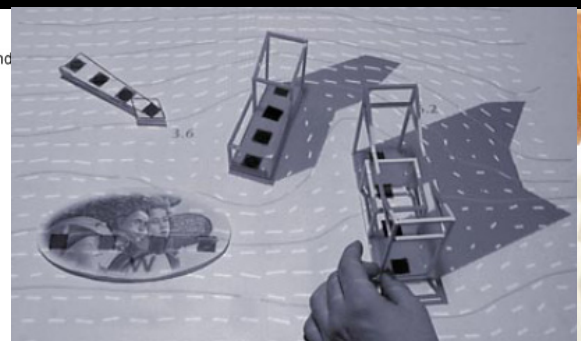
Like Model-View-Controller, except
Controller split between
Intangible (**P**hysical) and **T**angible (**D**igital)
Representations



(a) interaction model of GUI: MVC model (Smalltalk-80)

(b) interaction model of TUI: MCRit model

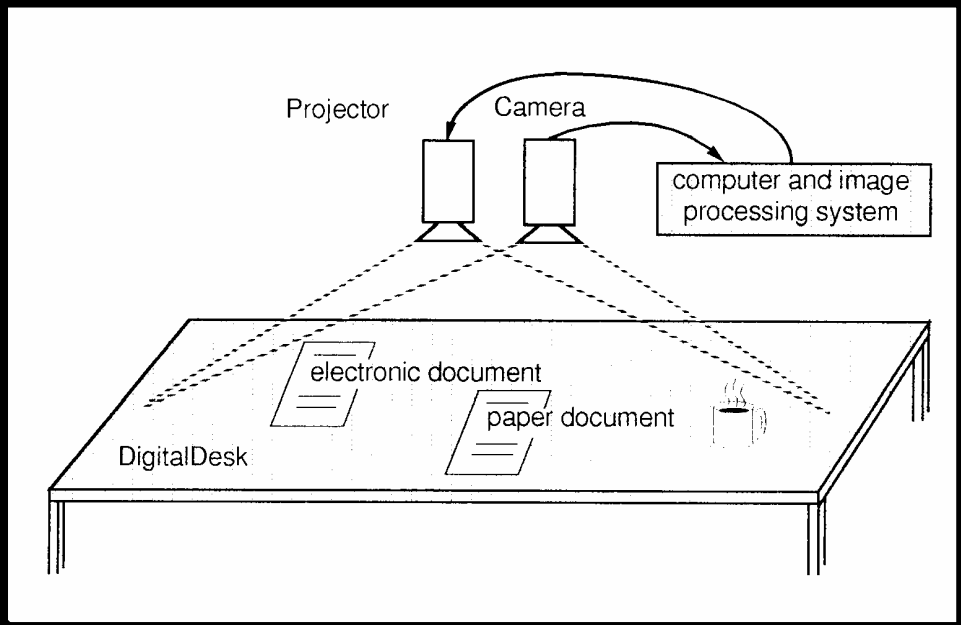
Fig. 9. MVC and MCRit interaction models.

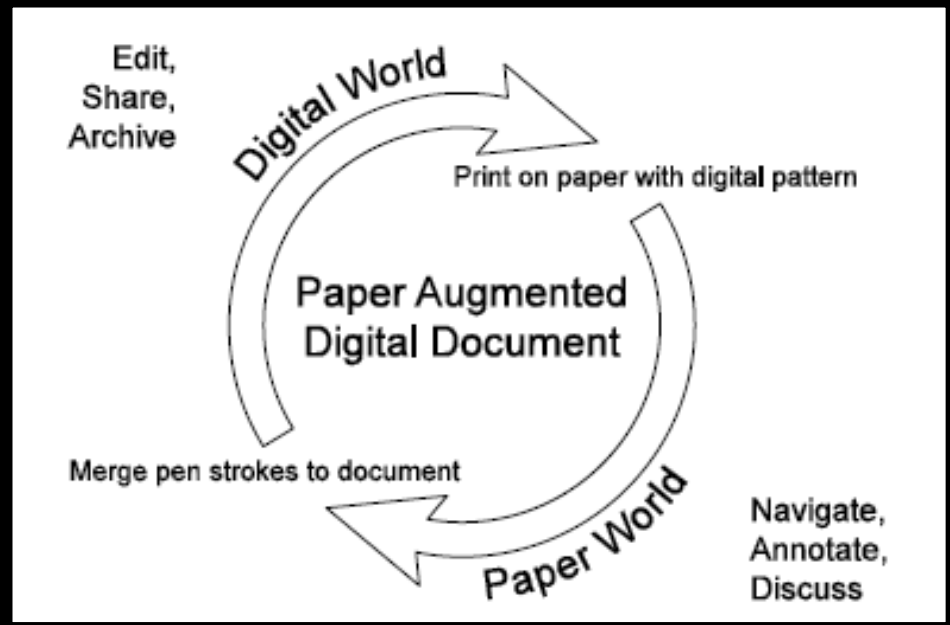


Paper-Digital Integration

[Wellner 1993]

[Guimbretière 2003]

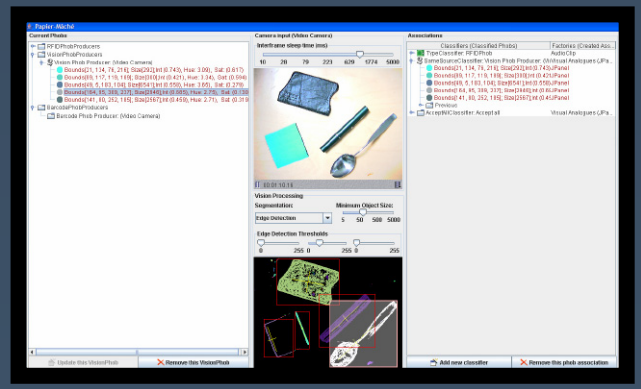




Physical-Digital Toolkits

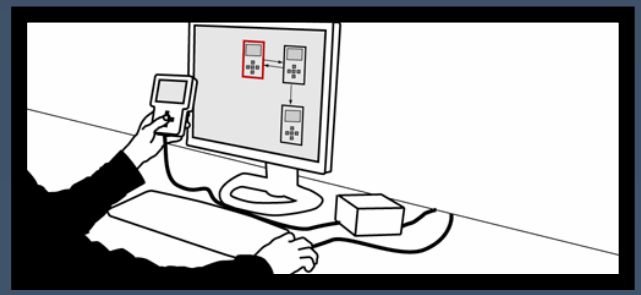
Papier-Mâché

- [Klemmer *et al.* 2004]
- vision, passive



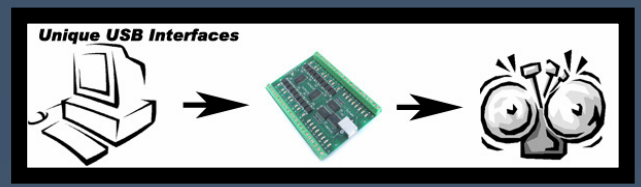
d.tools

- [Hartmann *et al.* 2006 (TR)]
- tethered, active



Phidgets

- [Greenberg & Fitchett 2001]
- tethered, active



Anoto Software Tools

Paper Buttons for Pre-Defined Actions

- With a Synchronization Step

Ink/Forms-Based Capture

Ink-Sample Level Abstraction

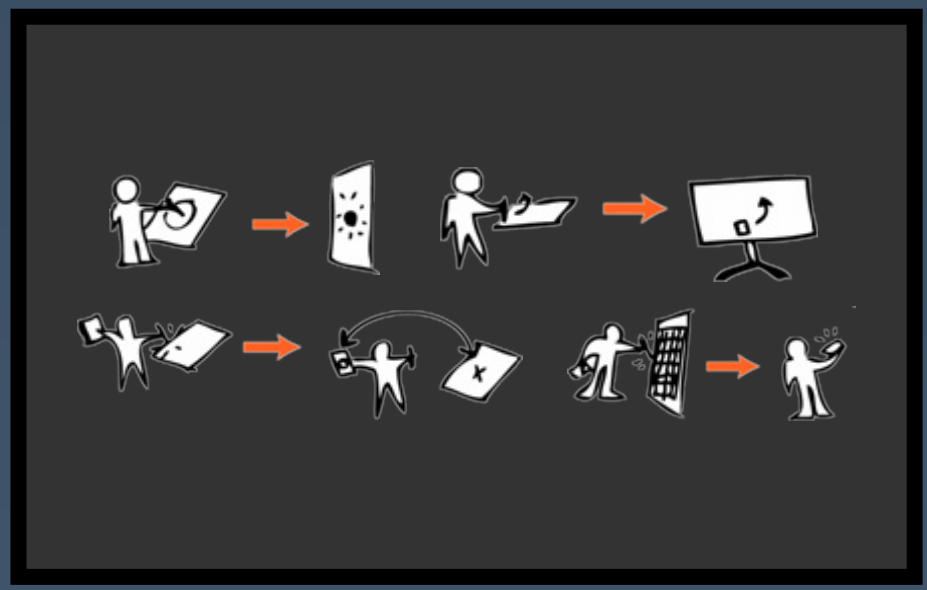
- OK for Programmers
- Wrong level for Most Designers and End-Users

We propose...

Duet: Paper-Digital Ensembles Toolkit

Interactions

- Select
- Manipulate
- Associate
- Transport



Support Iterative Design

[Design → Prototype → Test → Analyze]

Our Target Users

Designers

- Visual Authoring of Paper-Digital Interactions
- WOz Testing
- GUI to Facilitate Analysis of User Tests

Programmers

- Java & Python-Based Toolkit
- Event-Based Architecture
- Abstract Away “Dealing with Ink Samples on Paper”

Users (End-User Programming)

- Programming by Example
- Visual Authoring

Defined and Motivated Ensemble Interactions

Three Projects Demonstrating Them

Proposing Toolkit Support for Paper-Digital Ensembles

http://graphics.stanford.edu/~ronyeh

Ron B. Yeh
ronyeh@cs.stanford.edu