Foundations and Frontiers in Human-Computer Interaction

CIS 7000-001 University of Pennsylvania

This course reviews some of the most powerful ideas enabling great human-computer interaction (HCI), from the past to the present. The course covers classic visions of HCI futures like ubiquitous computing, embodied virtuality, and online collaboration that goes "beyond being there." In the course, we will take inventory of what progress has been made in these directions, and where work remains to be done. We will also cover theoretical paradigms and frameworks that have advanced how interactions are designed and evaluated, like theories of computer-supported collaborative work, models of human ability, and natural interaction. In-class instruction will consist of lectures and group discussion, with about one lecture and one discussion per major paradigm from HCI. Unlike other courses in HCI in the department, this course will primarily be focused on conceptual understanding rather than implementation and design practice. Students will read classical and emerging papers from the field and undertake a final research project representing a step forward in some major HCI paradigm.

Introductions

Andrew Head

Assistant Professor

Penn HCI

Office hours: on request

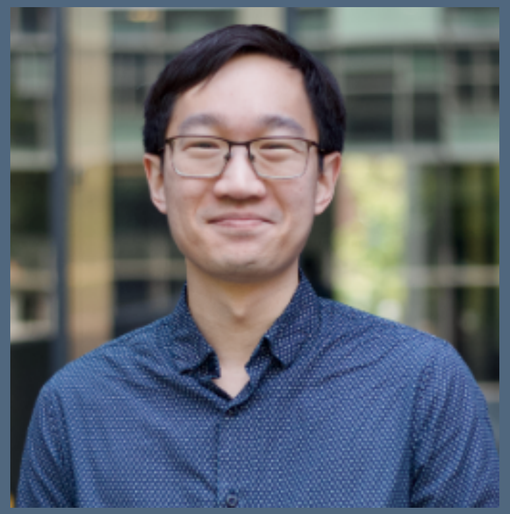
Danaé Metaxa

Assistant Professor

Penn HCI

Office hours: on request

Teaching staff



Jeffrey Tao
Head TA
PhD student

Ro Encarnación
TA
PhD student

Our Stanford forebears

Huge credit to the staff of CS 347 from Stanford, who over many years have created and refined these materials.

We will be sticking extremely close to them this whole semester. Everything, all the way down to the slides' visual theme.*

* You will be helping us figure out how to make them our own for future Penn students!

Michael Bernstein

Maneesh Agrawala

Phil Baillargeon
MS CS

Michelle Lam
PhD CS

Parker Ruth
PhD CS

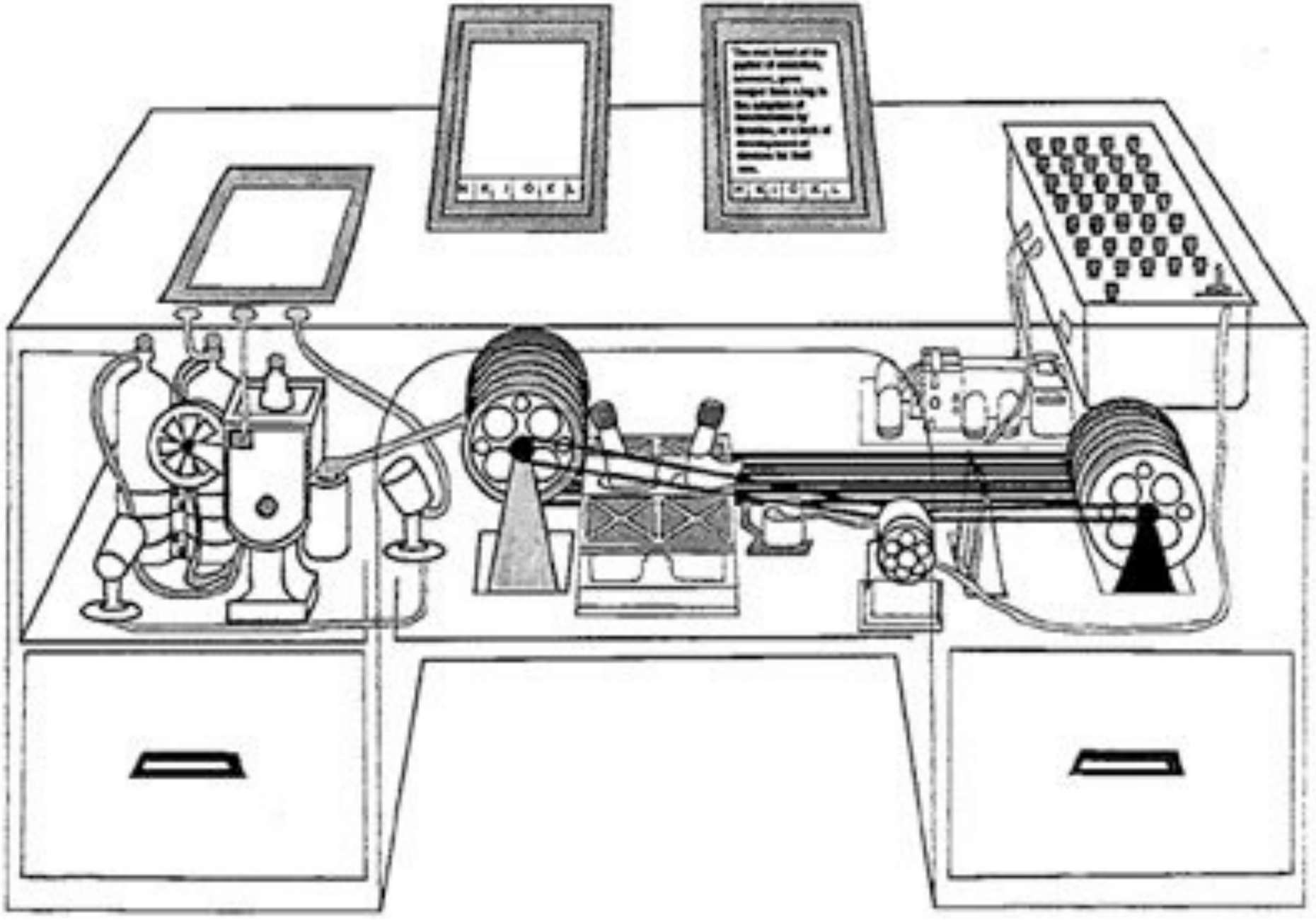
Miroslav Suzara
PhD Education
MS CS

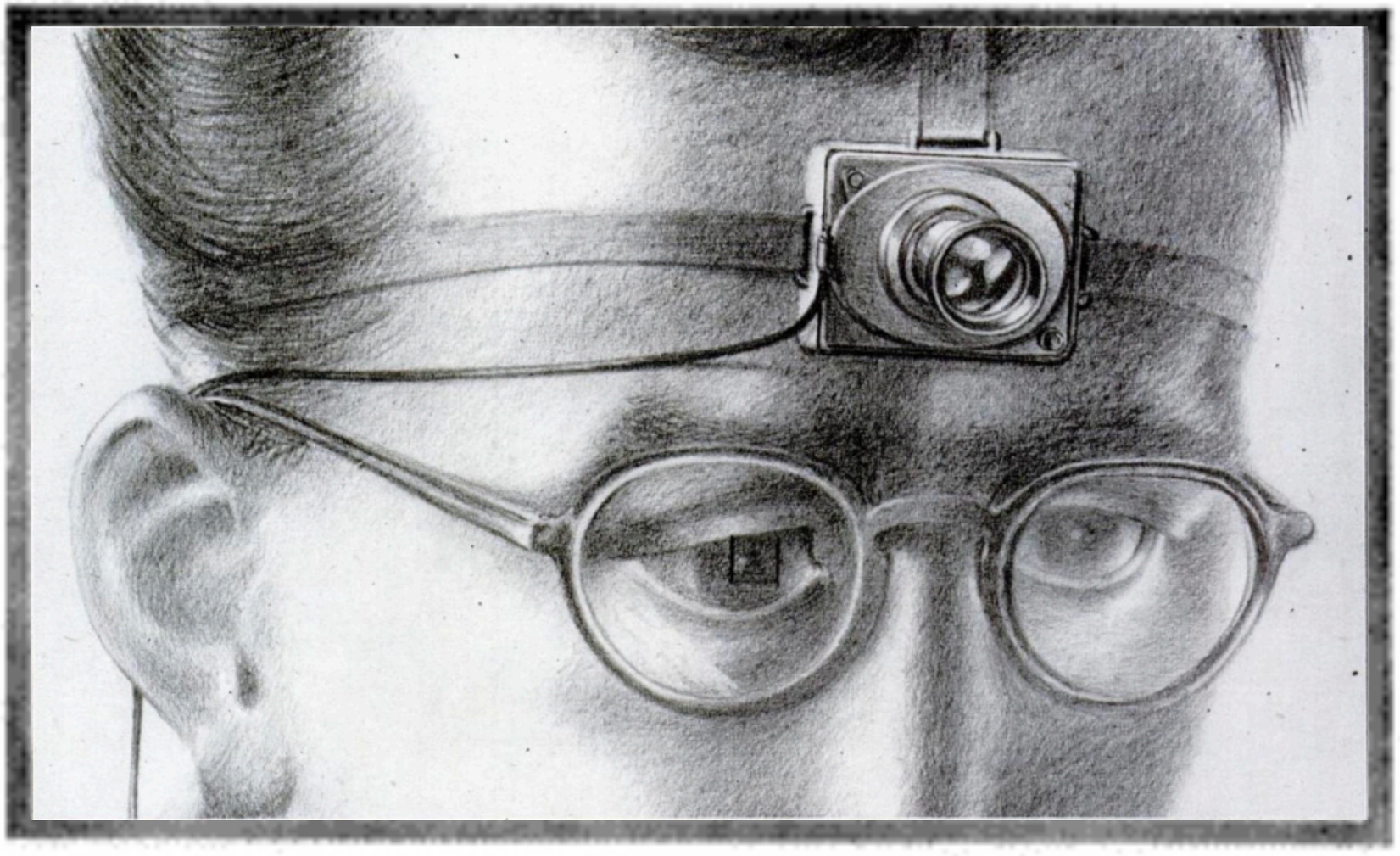
…and many others (instructors and TAs)

Introductions

How you like to be called.

A human-computer interaction question you are interested in.





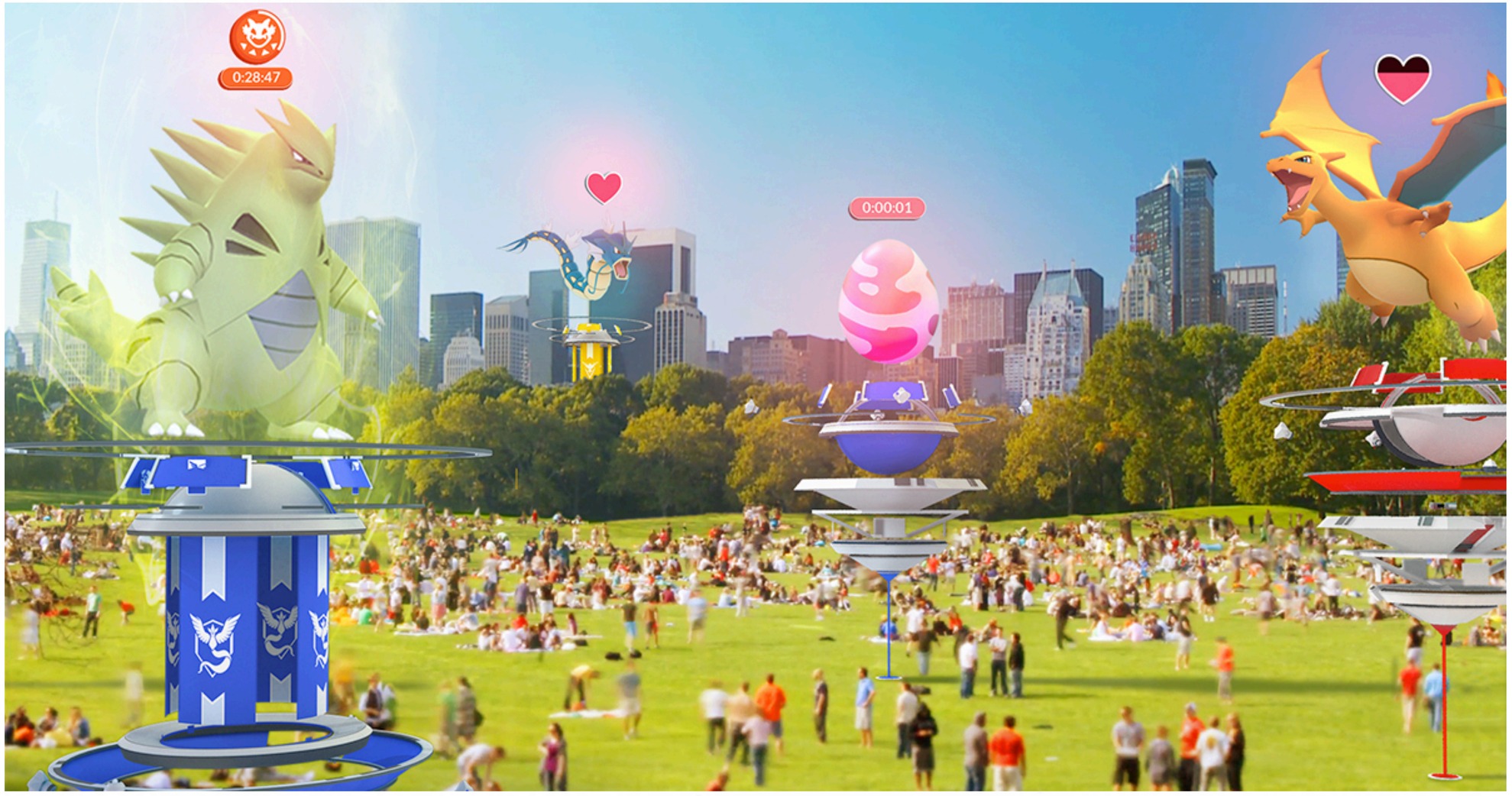
A scientist of the future records experiments with a tiny camera fitted with universal-focus lens. The small square in the eyeglass at the left sights the object (*LIFE* 19(11), p. 112).

[image from Wired]

A scientist of the future records experiments with a tiny camera fitted with universal-focus lens. The small square in the eyeglass at the left sights the object (*LIFE* 19(11), p. 112).

[image from apple]

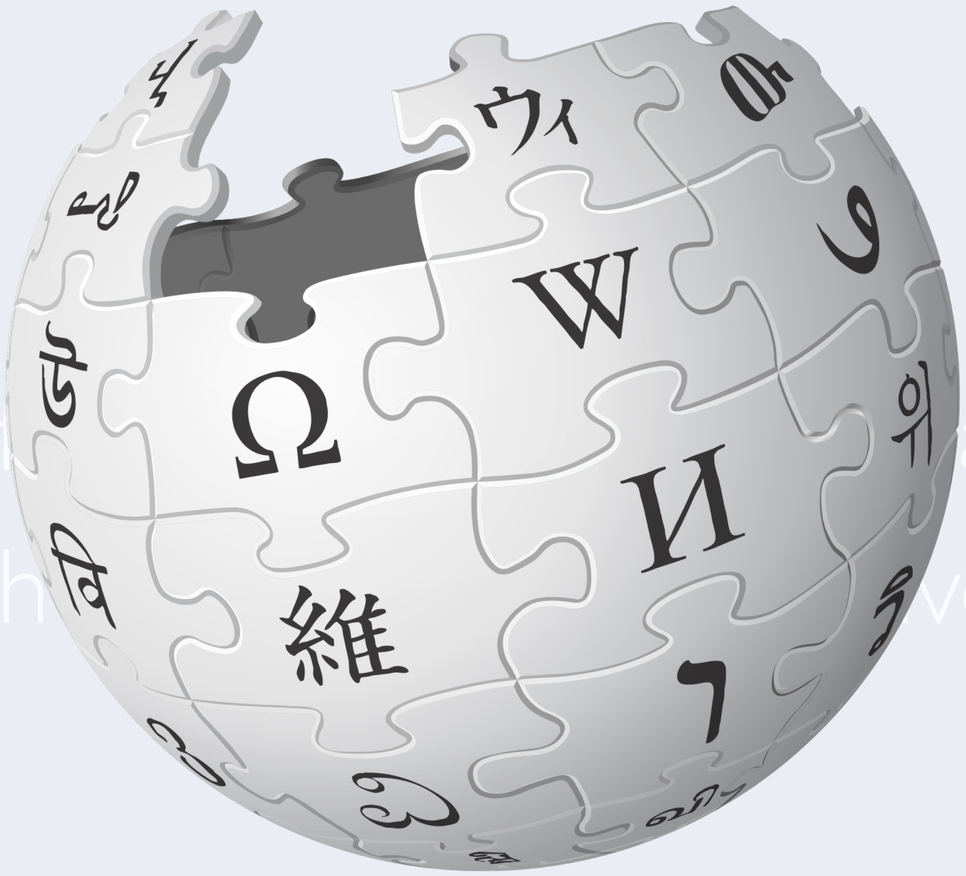
A scientist of the future records experiments with a tiny camera fitted with universal-focus lens. The small square in the eyeglass at the left sights the object (*LIFE* 19(11), p. 112).



A scientist of the future records experiments with a tiny camera fitted with universal-focus lens. The small square in the eyeglass at the left sights the object (*LIFE* 19(11), p. 112).

“Wholly new forms of encyclopedias will appear, ready-made with a mesh of associative trails running through them.”

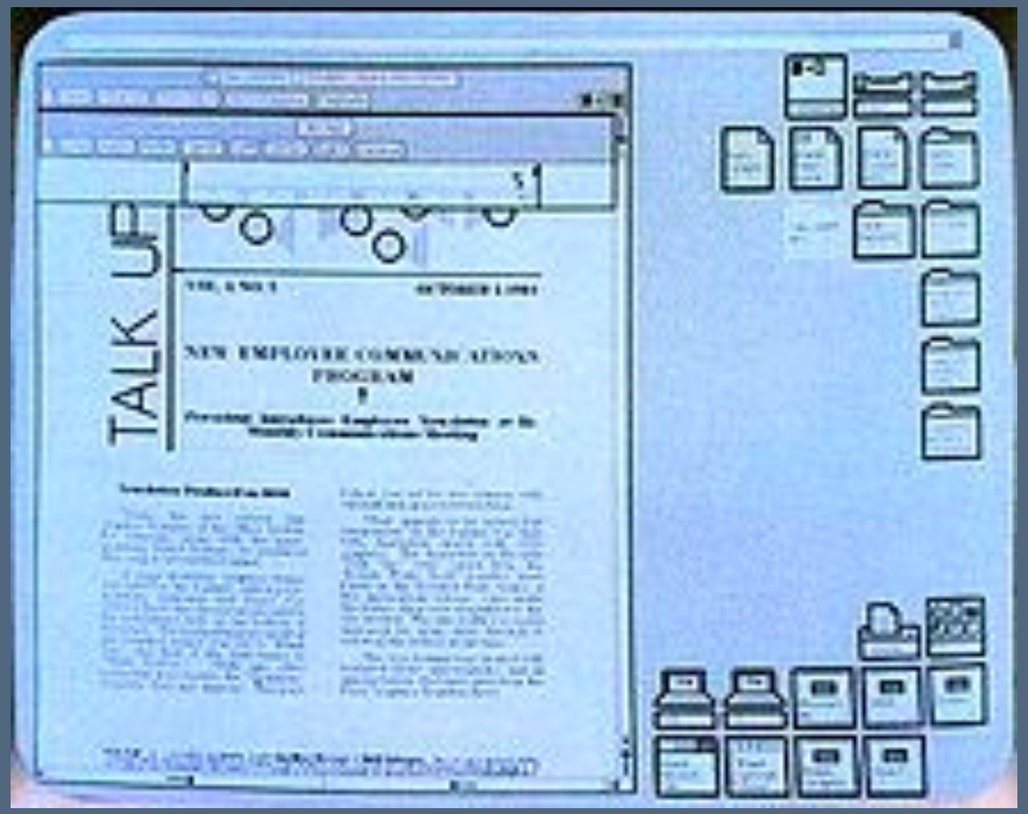
“Wholly new [illegible] as will appear, ready-made with [illegible]ve trails running through them.”



WIKIPEDIA

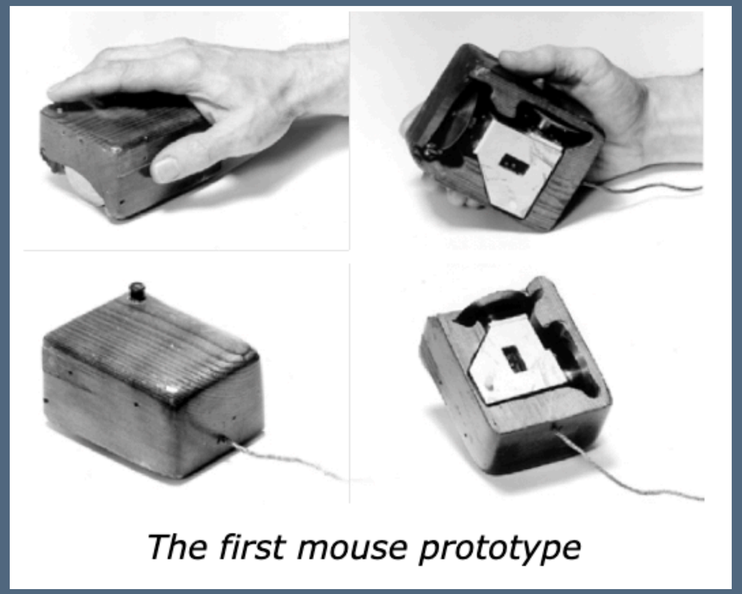
The Free Encyclopedia

Xerox PARC. 1973.
The Xerox Alto.

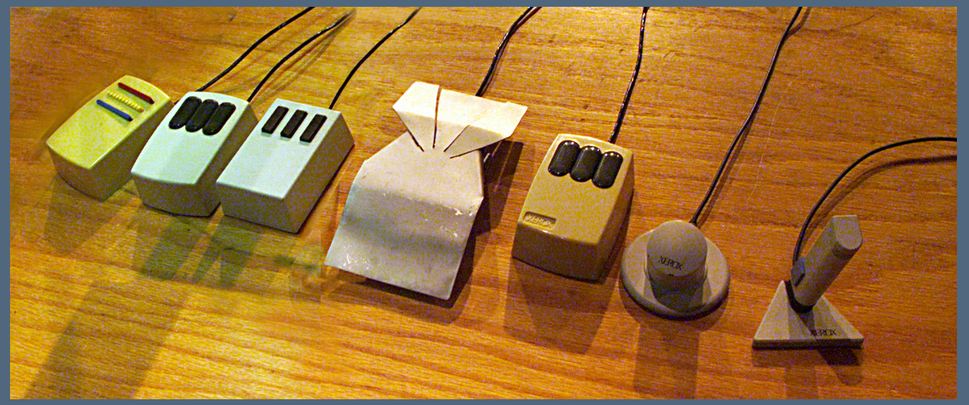


Modern MacOS desktop

Engelbart 1963-64
First mouse prototype

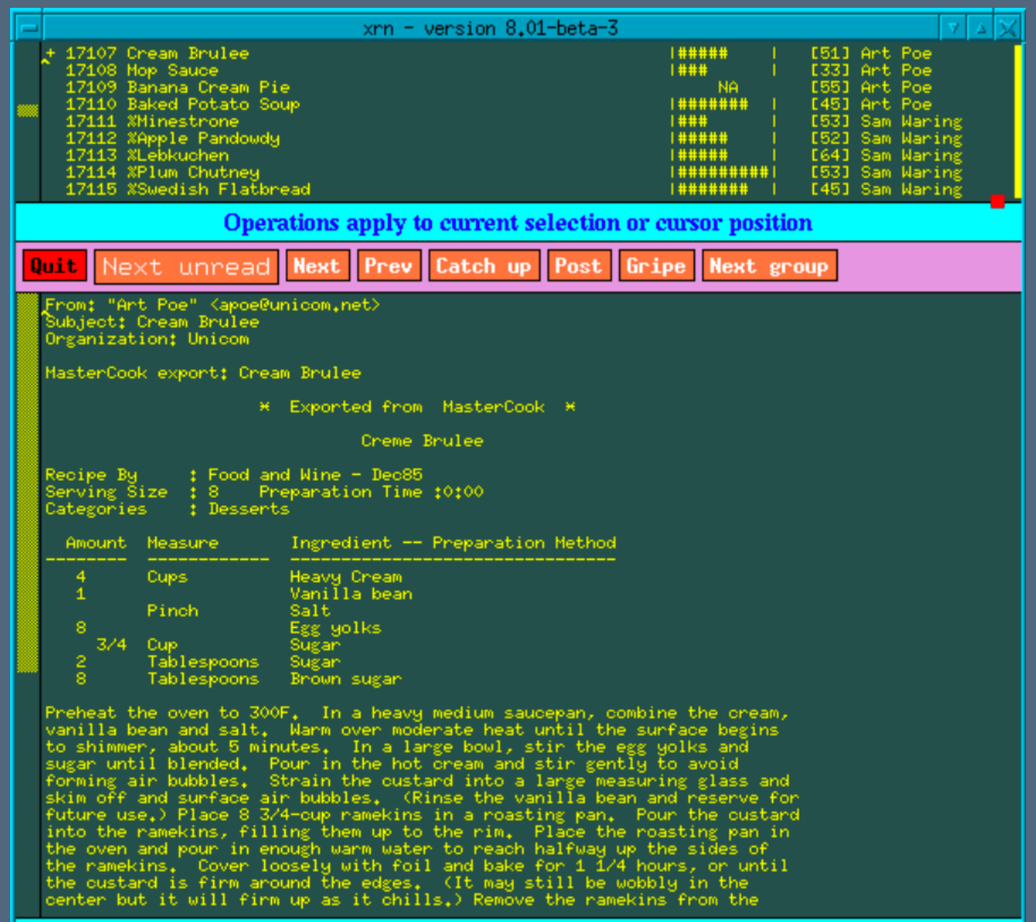

The first mouse prototype

Card, English and Burr. 1978.
Evaluation of mouse, rate-controlled isometric joystick, step keys, and text keys for text selection on a CRT.

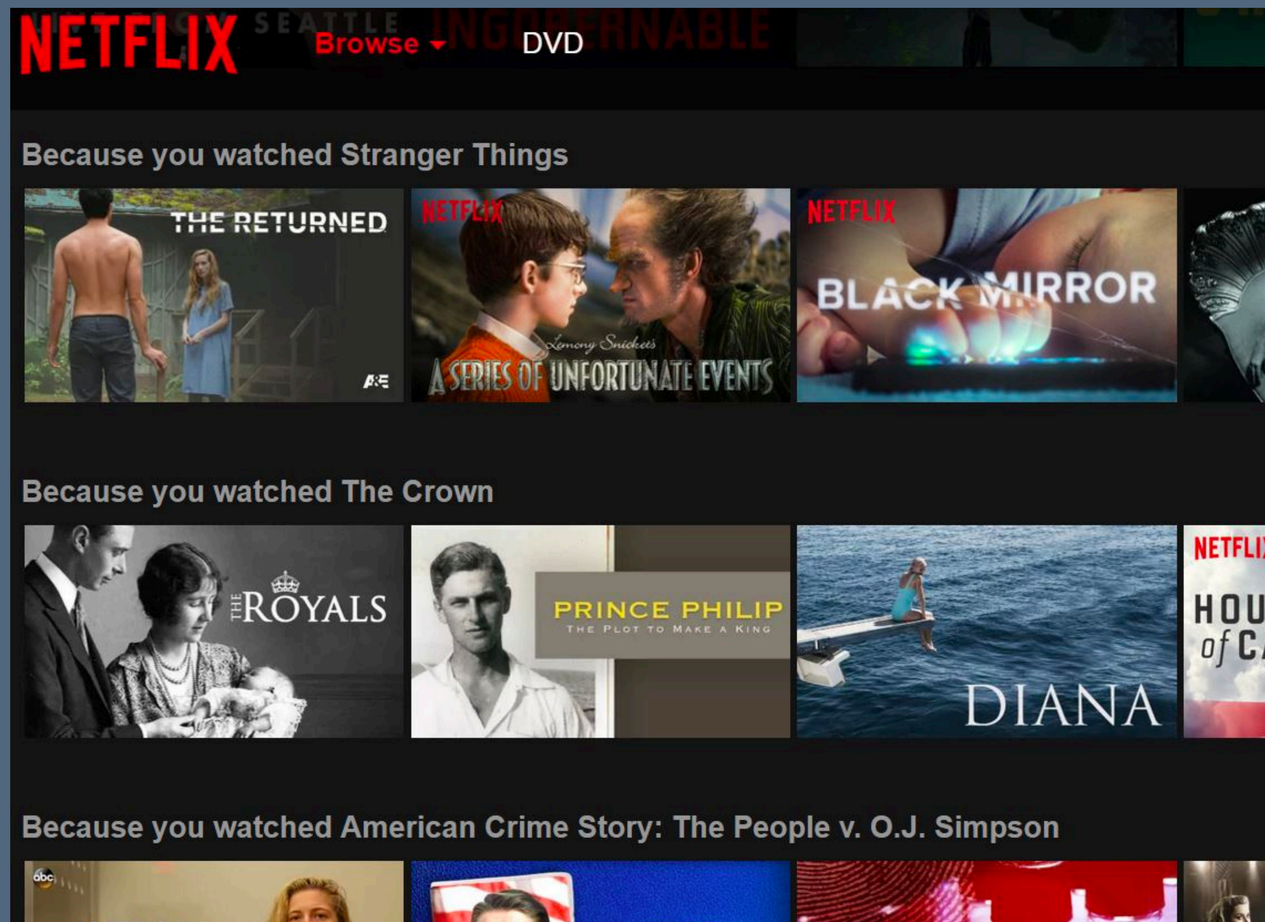


Modern mouse

Resnick et al. 1994. GroupLens: an open architecture for collaborative filtering of netnews.



Modern recommender systems [image from HBS]

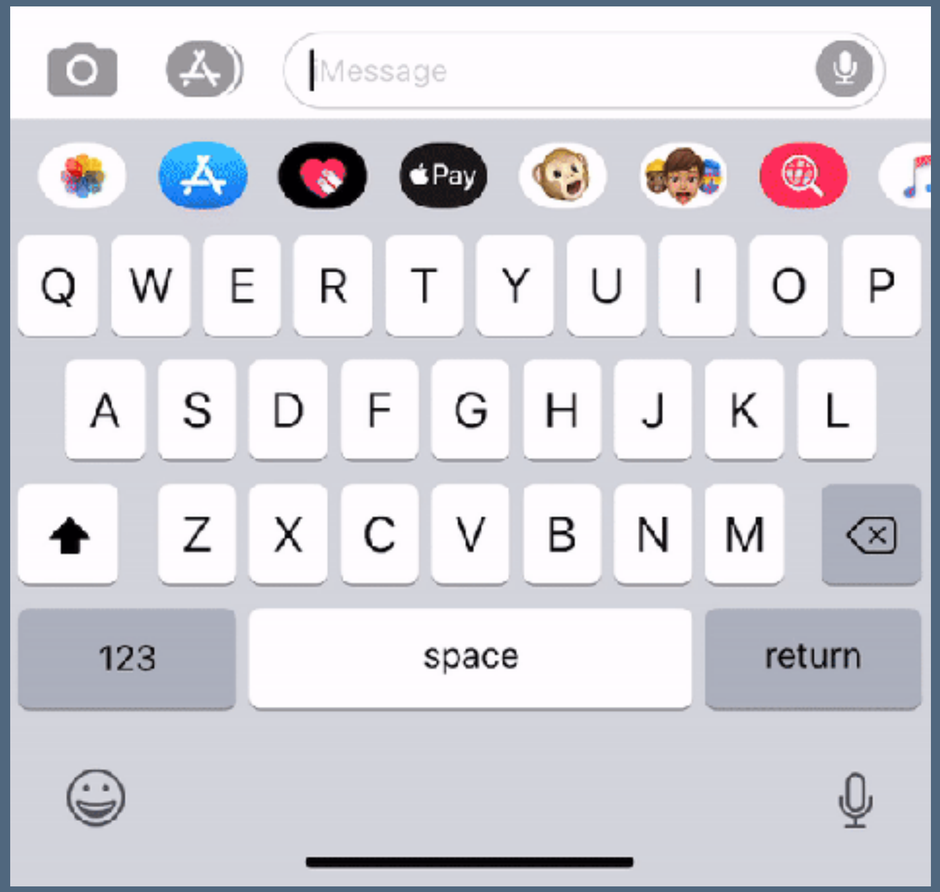


Fiala. 2005. ARTag, a fiducial marker system using digital techniques.

QR codes, visual augmented reality markers

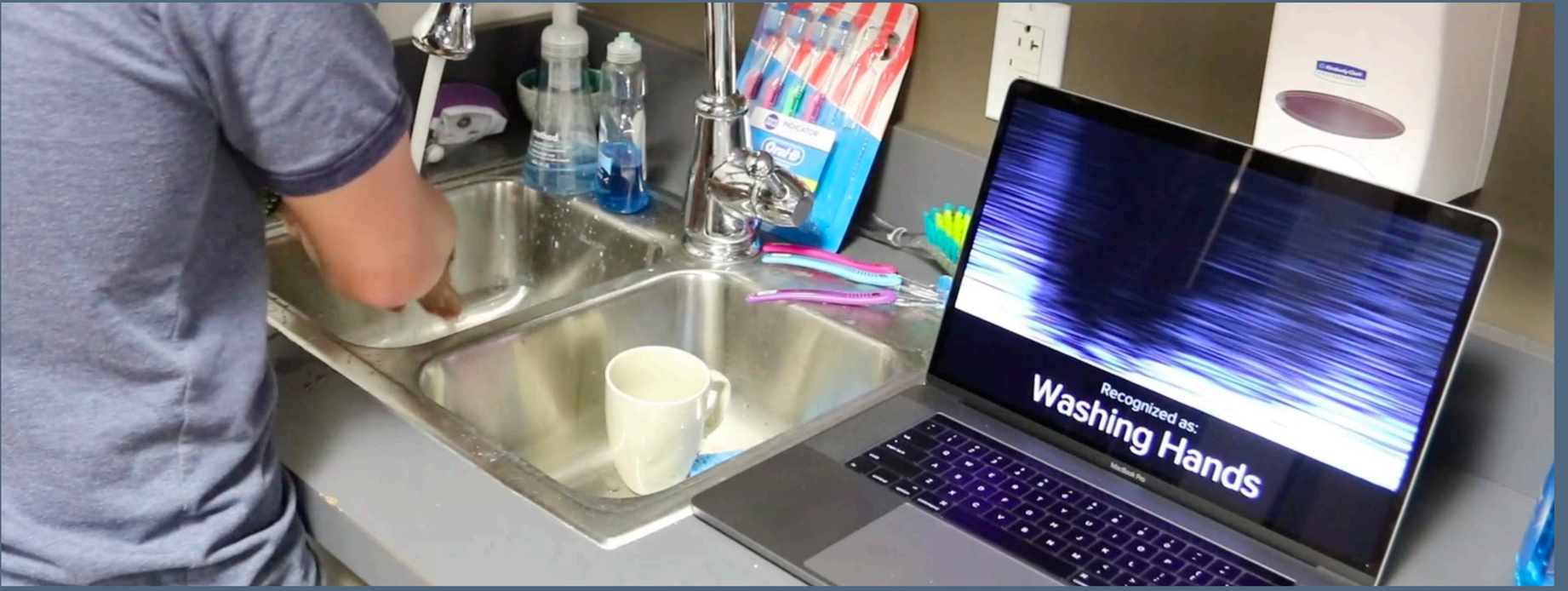
Zhai and Kristensson. 2003. Shorthand writing on a stylus keyboard.

Swipe keyboards (iOS, Android) [image from 9to5mac]



Consolvo et al. 2008. Activity sensing in the wild: a field trial of UbiFit Garden.

Modern fitness trackers [image from Apple]

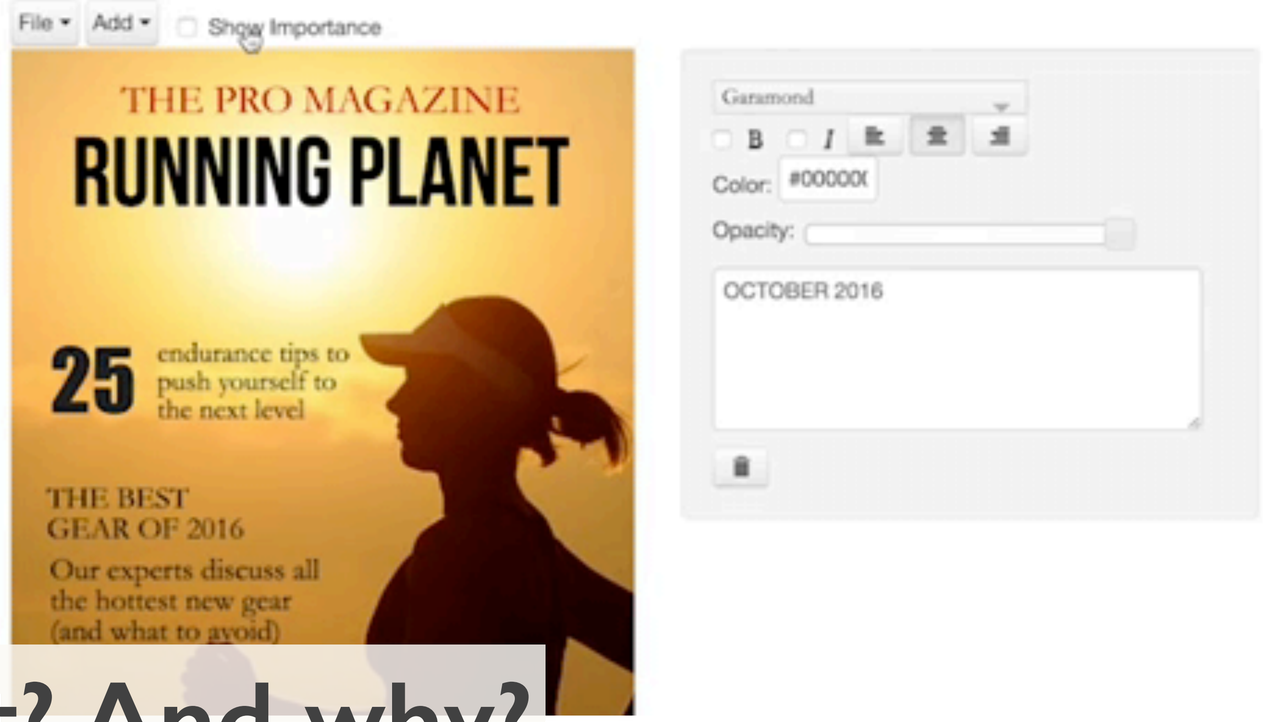


Laput et al. 2018. Ubicoustics: Plug-and-Play Acoustic Activity Recognition

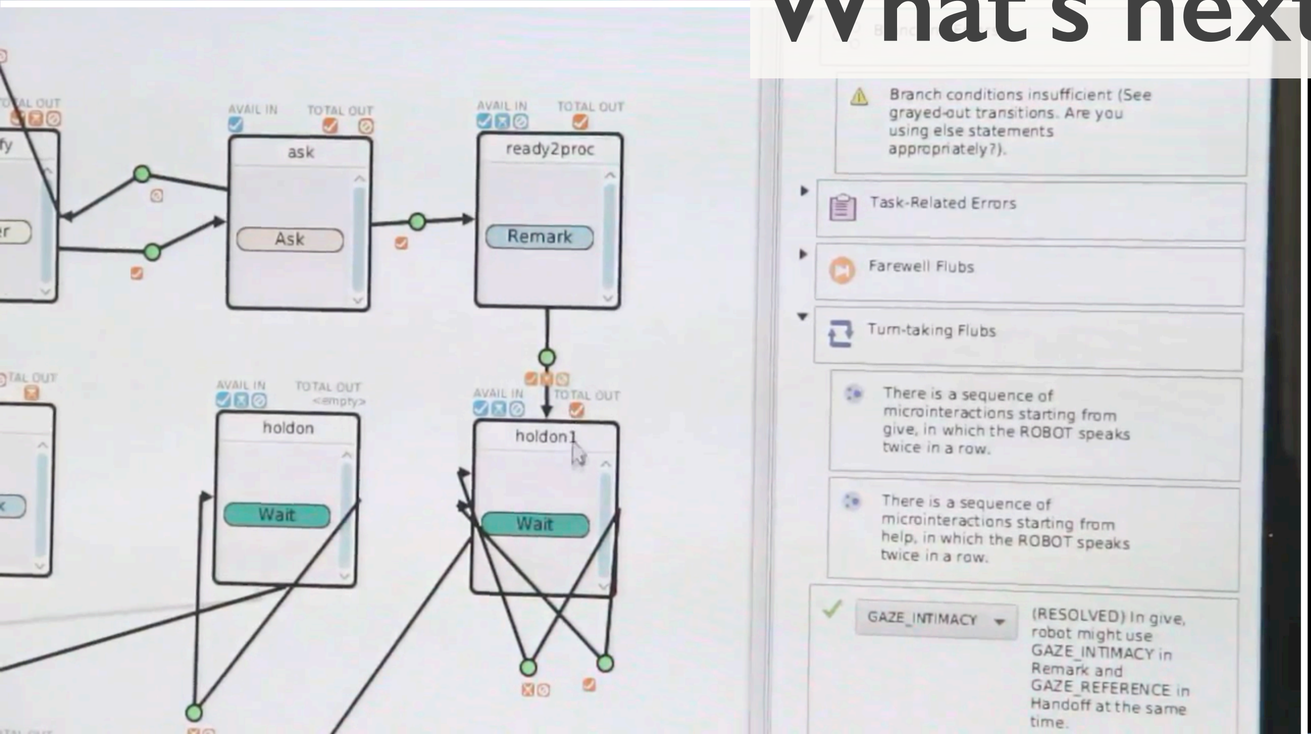
Apple Watch handwashing detection 2020

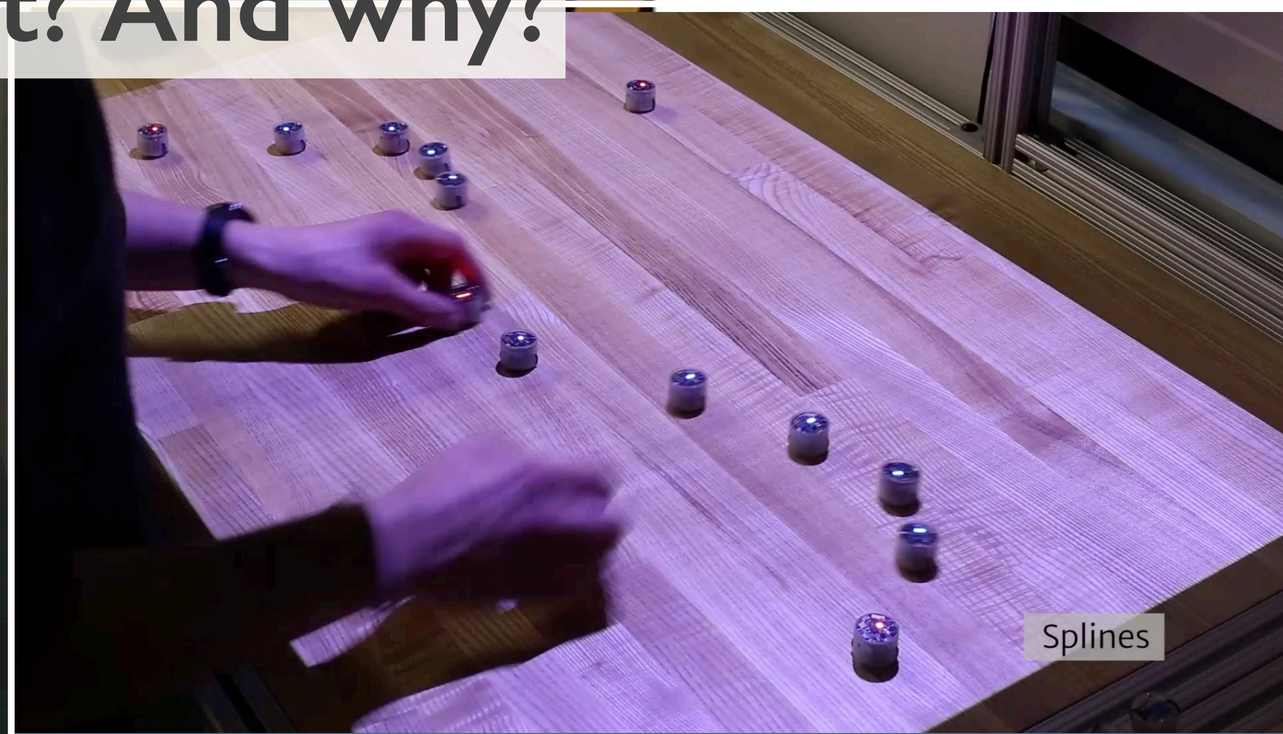
Zhang et al. 2021. AI-powered screen reader accessibility.

iOS Screen Recognition



What's next? And why?





"How about a virtual reality headset that uses blockchain technology to securely store user data and personalize the VR experience using deep learning algorithms? The headset would be able to analyze a user's brain activity and eye movements in real-time to continuously adapt the VR content to their preferences and interests. It would also use blockchain to store a record of the user's interactions within the VR world, allowing them to seamlessly switch between devices and pick up where they left off. This technology would revolutionize the way we experience virtual reality, making it more immersive and personalized than ever before."

Why is this a bad idea?

(ChatGPT prompt: "Generate a tech product idea that is full of technobabble about VR, blockchain, and deep learning")

This class

Envisioning and understanding
the future of interaction
between people, society, and technology

This class

Teaches foundational theories
and modern frontiers

Learning goals

This is not like other HCI classes (4120, etc.).

Your goal is **not** just to **design** an alignment between people and technology.

Your goal is to articulate, critique, and generate entirely new ideas about that relationship.

Foundations and frontiers

You will learn the major theories and concepts that underpin HCI

You will engage in critical analyses of these theories and concepts, apply them, and extend them


START

Ubiquitous computing

Unit 1

ubiquitous and tangible computing
input and output
activity, health, and behavior

The future of interaction?

[Microsoft]

The future of interaction?

[Victor 2011]

Mobile phone's
model of a person

[O'Sullivan and Igoe 2004]

"…this vision, from an interaction perspective, is *not visionary*. It's a timid increment from the status quo, and the status quo, from an interaction perspective, is actually rather terrible." – Bret Victor

http://worrydream.com/ABriefRantOnTheFutureOfInteractionDesign/

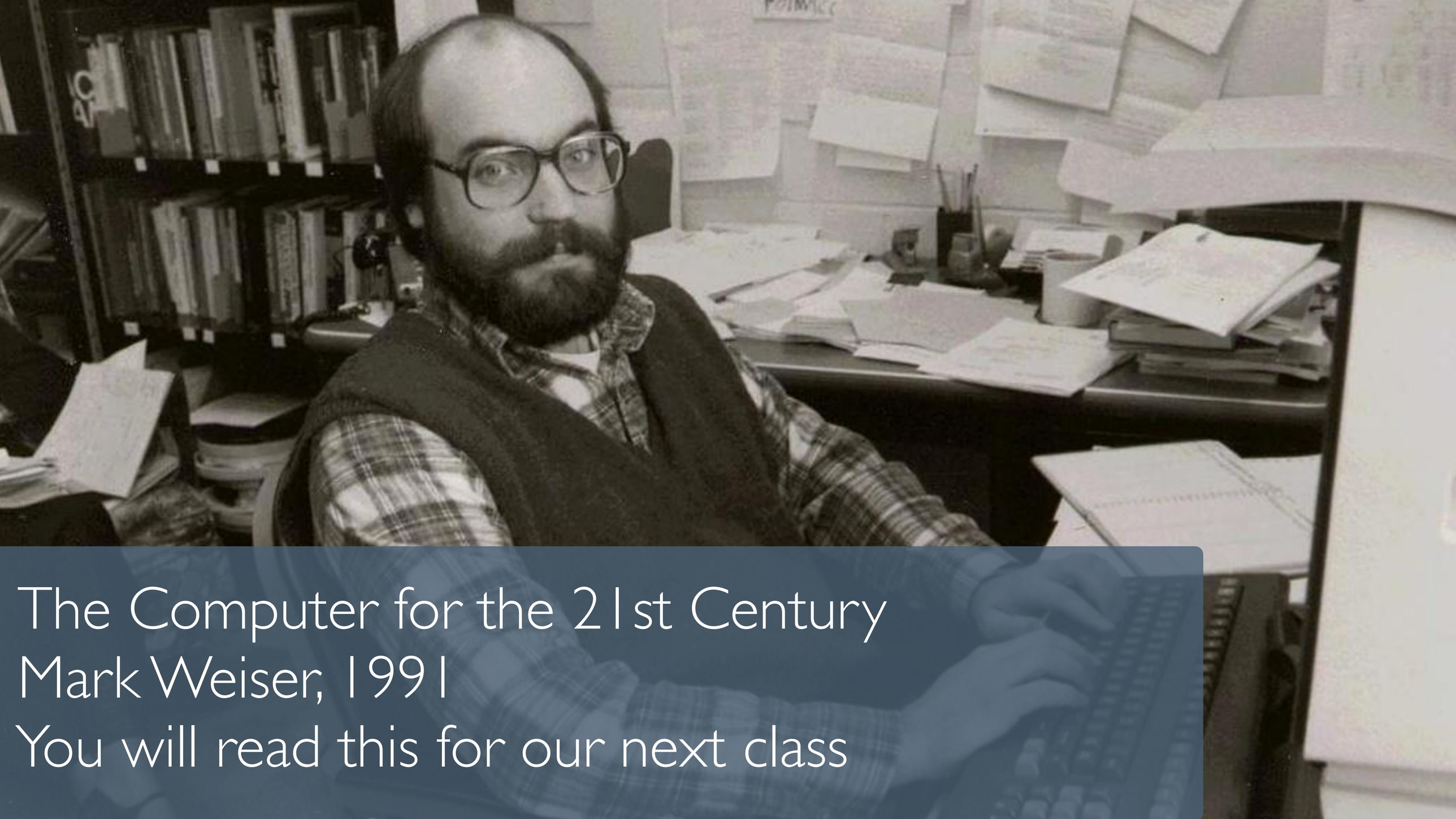
vs. "Pictures Under Glass"
[Victor 2011]

Why is this so terrible?

[Hutchins 1995, Dourish 2004; Klemmer, Hartmann, Takayama 2006]

Our cognition leverages **embodiment**—our bodies:

- We learn through interaction with the world
- We leverage the environments around us to make us smarter
- We communicate our intent through much broader mechanisms than just our fingertips: consider musicians, dancers, construction workers, professors on stage trying to get your attention



The Computer for the 21st Century
Mark Weiser, 1991
You will read this for our next class

“The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it.”
– Mark Weiser

[Weiser 1991]

Ubiquitous Computing [Weiser 1991]

Ubiquitous computing: a vision in which computers **"vanish into the background"** rather than focus our attention on a single box

This vision requires interactive systems to become reactive, context-aware, ambient, and embedded in everyday activities

Activity recognition [Laput et al. 2015]

Detecting ambient EM signals transmitted through body using commodity smart watch

Context-aware computing

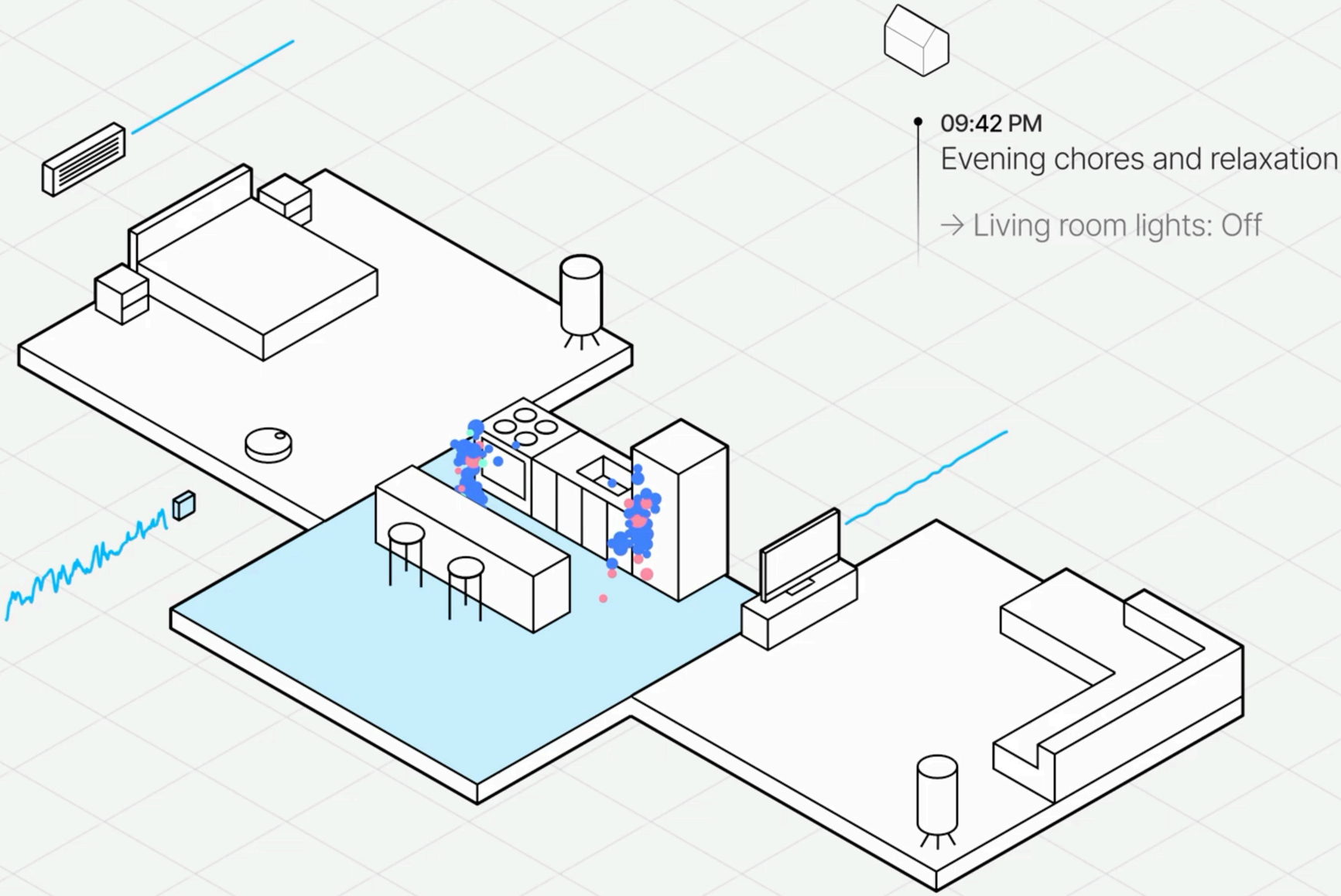
Collect information about the user's environment, and use it to customize their computing experience

Some types of context: location, social surroundings, activity level

But beware overuse of the term 'context'!

Towards a Better Understanding of Context and Context-Awareness

Anind K. Dey and Gregory D. Abowd



Ivan Poupyrev's Archetype AI: https://www.youtube.com/watch?v=LTb0HomV18Y

Programmable objects [Jin et al. 2019]

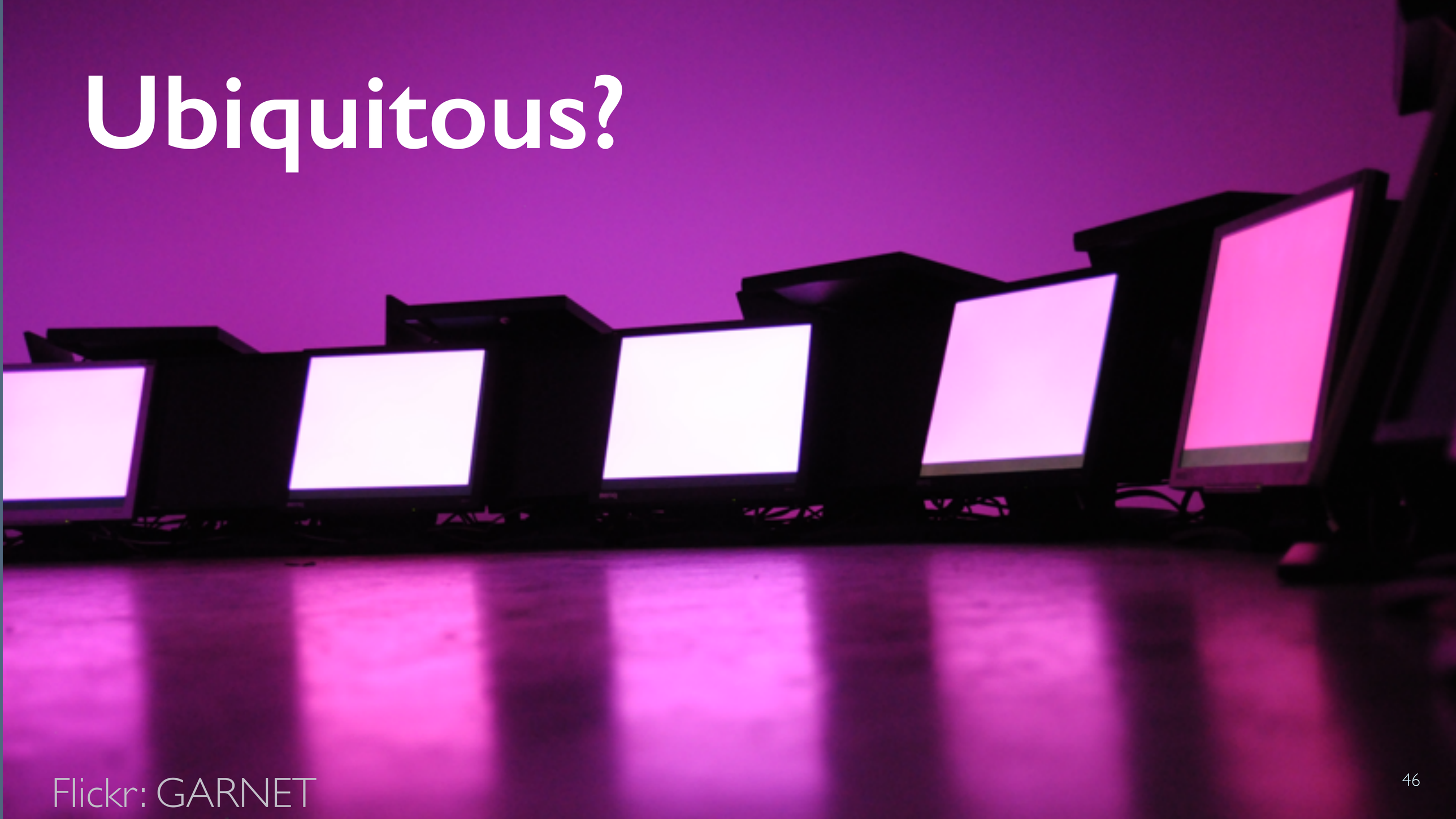
Photochromic inks change color when exposed to lights of a specific wavelength

Privacy [Chen et al. 2020]

Wearable microphone jamming: ultrasonic speakers are read as white noise by mics

Wearing the bracelet means the speakers move, so we get better coverage

Ubiquitous?



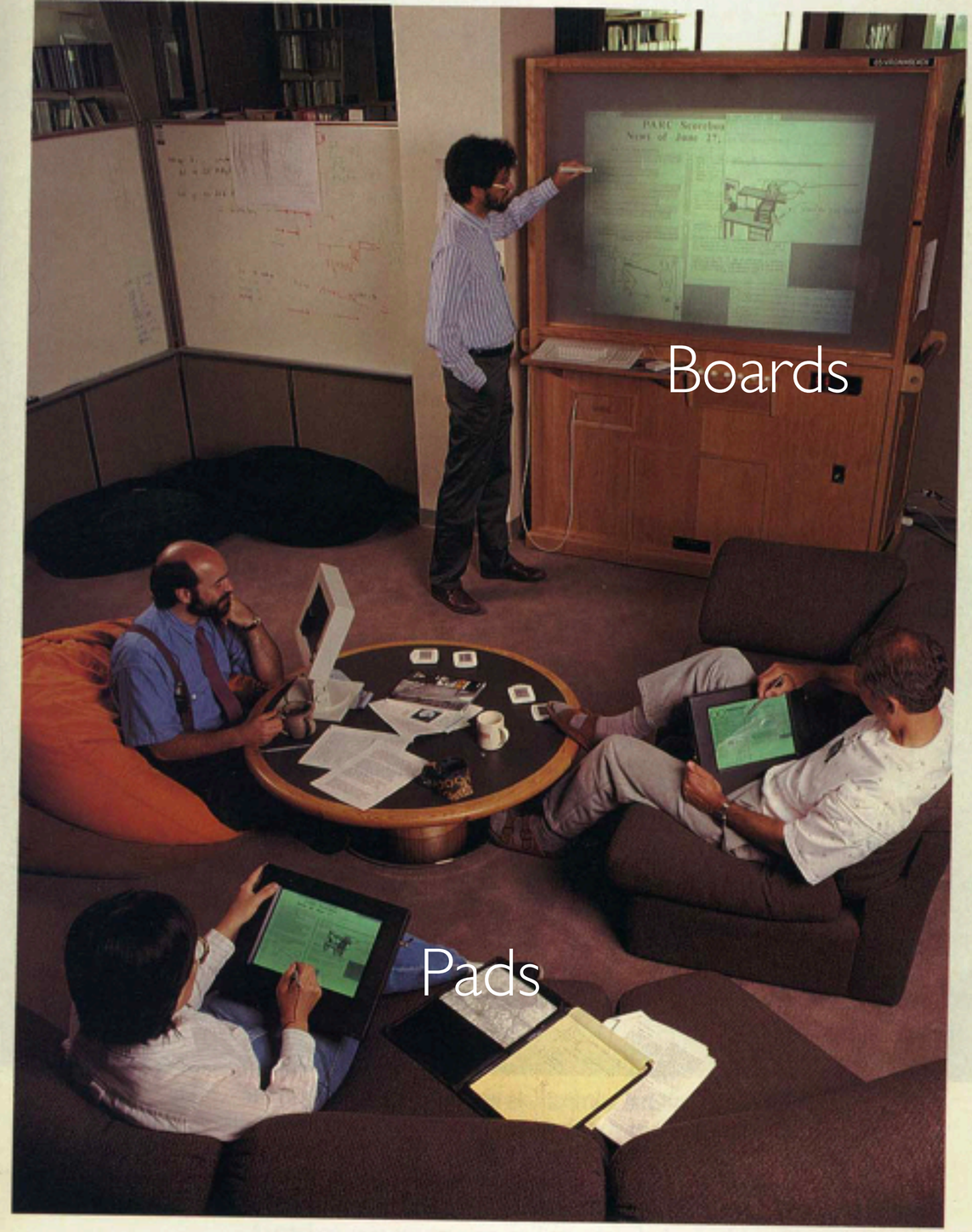
Flickr: GARNET

Ubiquitous?

Ubicomp is backgrounded

What Weiser calls one of the first "calm" technologies: Live Wire, a wire on a stepper motor, monitoring net traffic [Jeremijenko 1995]

Weiser envisioned ubiquitous computing devices at three scales: tabs, pads, and boards.



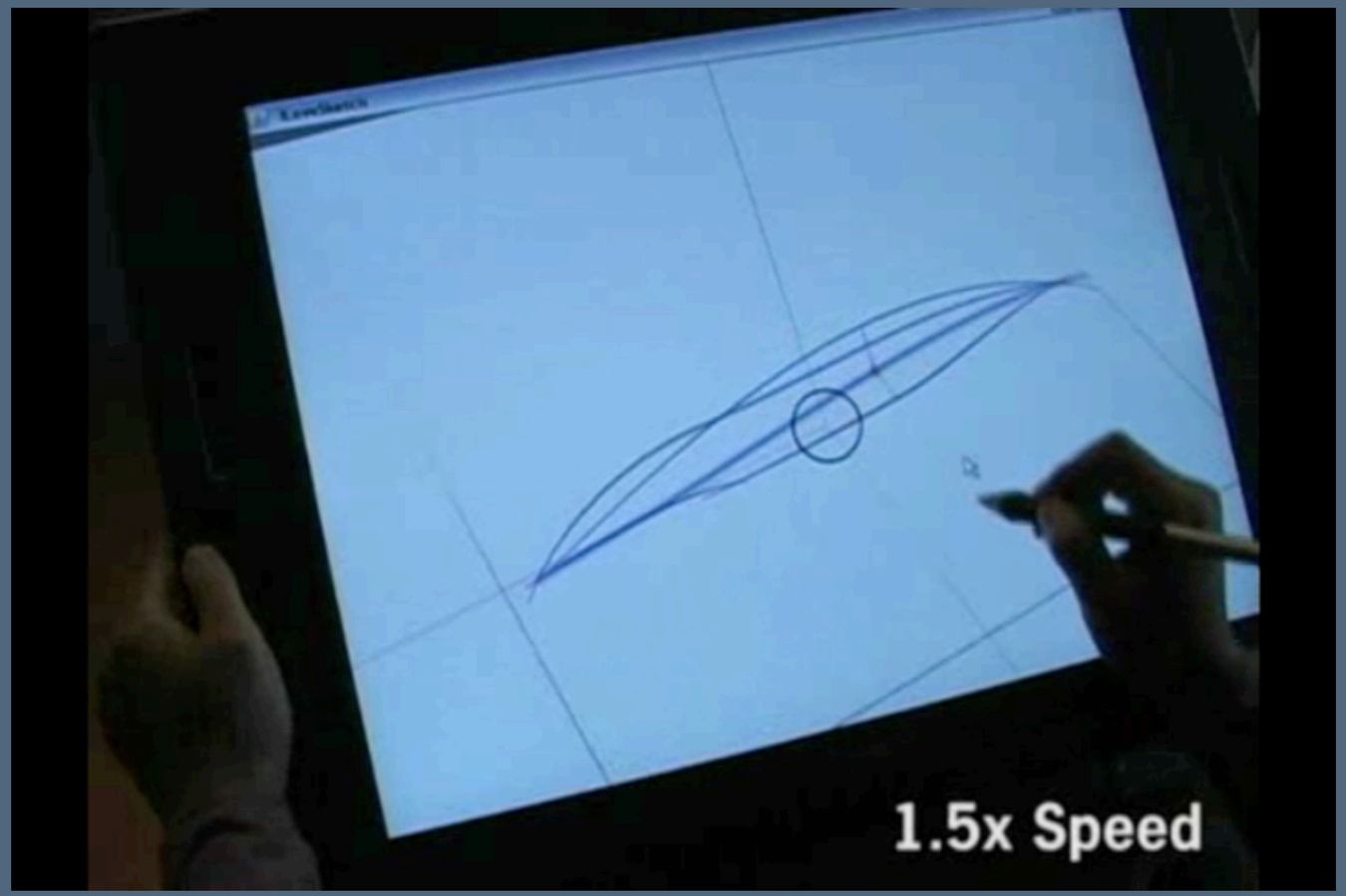
Tabs

Most similar to today's smart watches

Significant Otter: sharing biosignals with romantic partners [Liu et al. 2021]

Pads

Most similar to today's tablets



[Bae, Balakrishnan, and Singh 2008]

[Hinckley et al. 2010]

Boards

Create a grid of conductive diamonds similar to a phone screen

Sense the columns and scan the rows to ID the touch location

[Zhang et al. 2018]

Tangible computing

Tangible Computing

Directly-manipulable physical interfaces to data and computation

'Pure' form of ubicomp in that there is no computer to be seen

You will read this for our next class

Tangible Bits: Towards Seamless Interfaces between People, Bits and Atoms

Hiroshi Ishii and Brygg Ullmer
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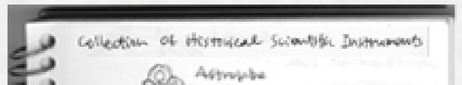
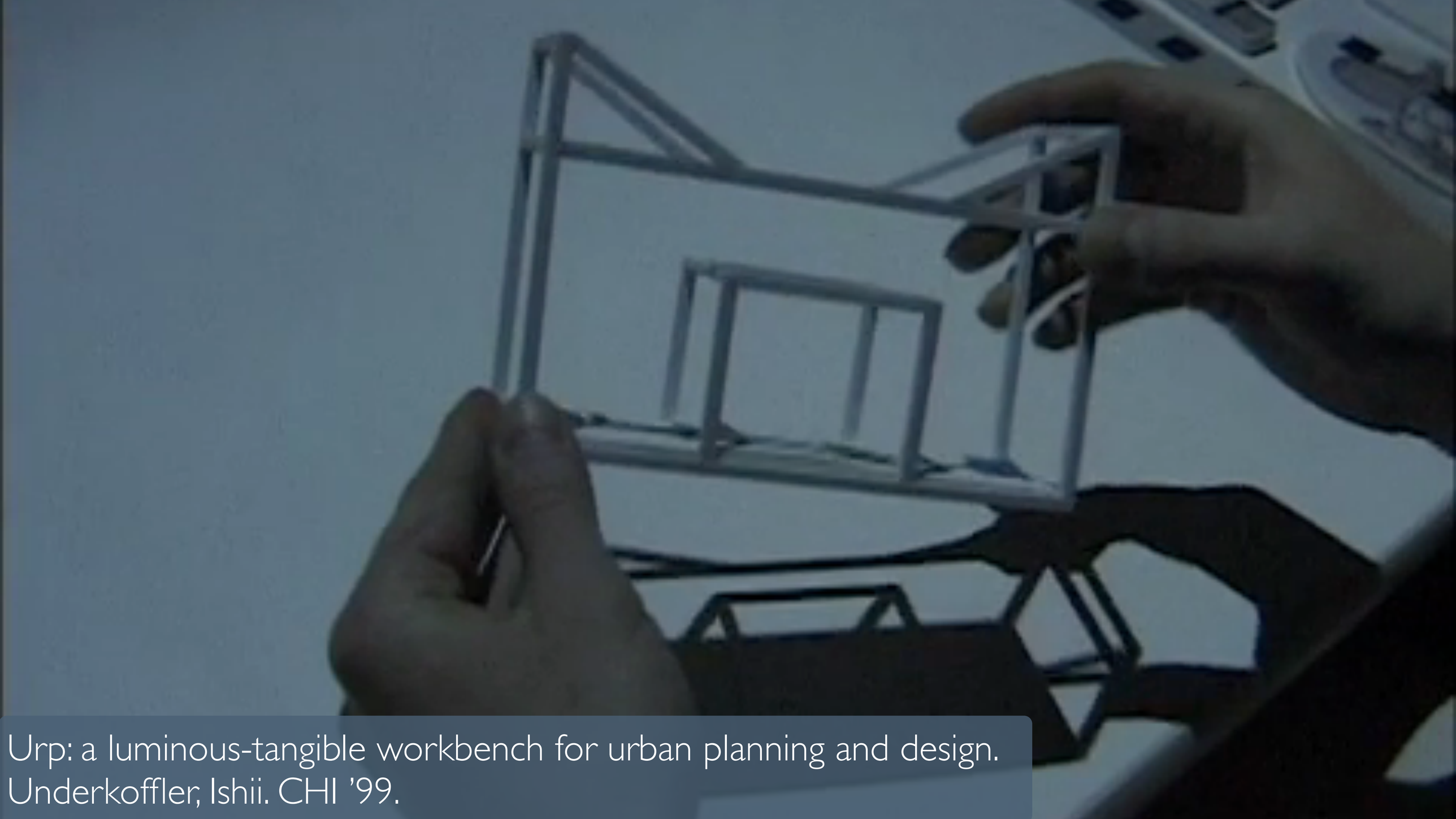
Tangible Media Group
20 Ames Street, Cambridge, MA 02139-4307 USA
{ishii, ullmer}@media.mit.edu

ABSTRACT
This paper presents our vision of Human Computer

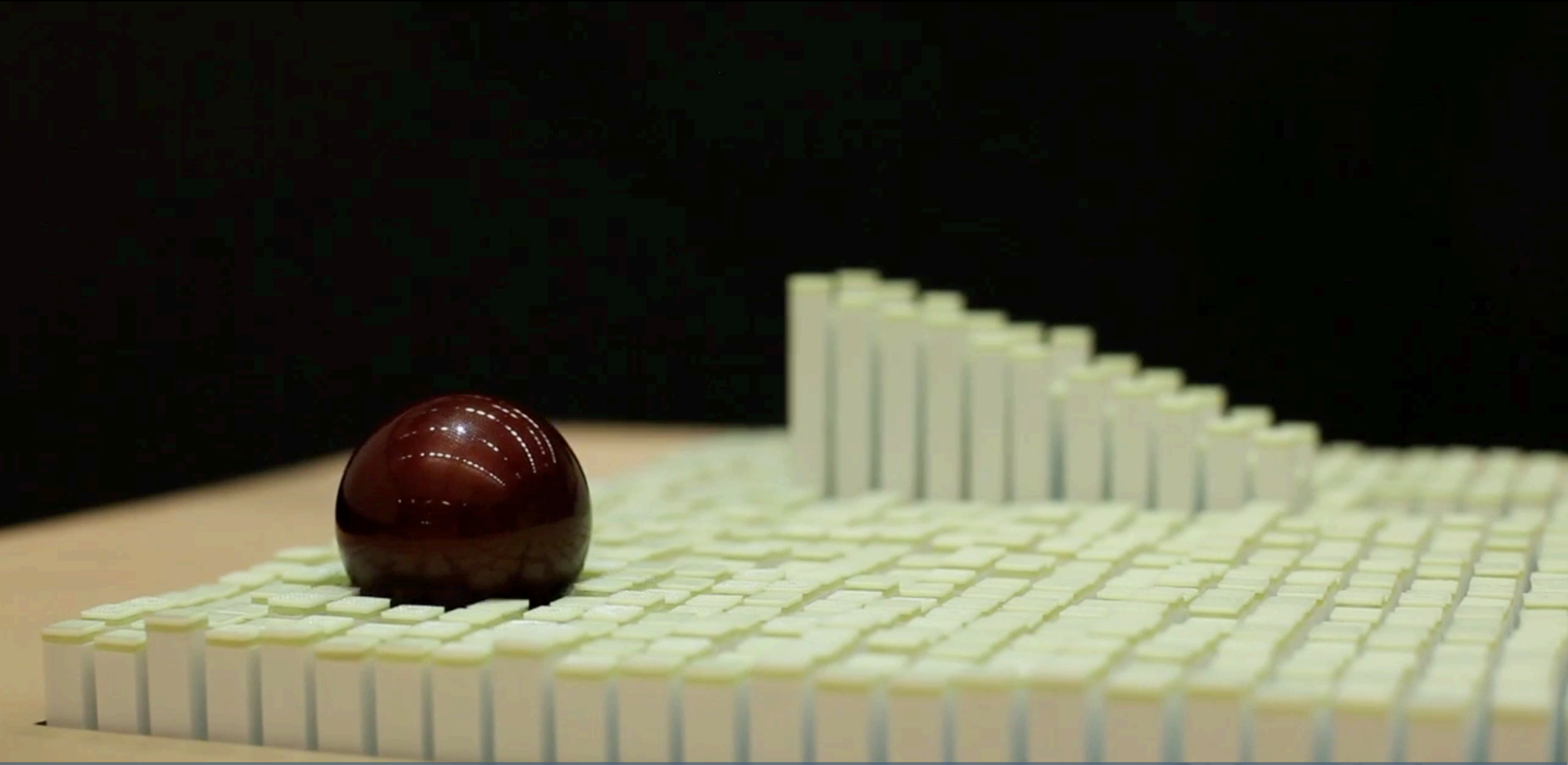
BITS & ATOMS
We live between two realms:





Urp: a luminous-tangible workbench for urban planning and design.
Underkoffler, Ishii. CHI ’99.

Urp: a luminous-tangible workbench for urban planning and design.
Underkoffler, Ishii. CHI ’99.



Follmer, Leithinger, Olwal, Hogge, Ishii. inFORM: Dynamic Physical Affordances and Constraints through Shape and Object Actuation. UIST '13.

Questions you ought to be asking

Why do, and don't, we have elements of the ubiquitous and tangible computing visions in our lives today, thirty years later?

What are resilient challenges or mistaken assumptions, and what challenges might we actually be able to tackle?

Yesterday's tomorrows

[Bell and Dourish 2007]

Ubiquitous computing is driven not by a technological goal, but by a shared vision of the future.

However, this vision is a future as imagined in 1991.

What should the future of ubicomp be, from today's perspective?

Where we go from here

week 1	Ubicomp (today)
week 2	Ubicomp
week 3	Design
week 4	Design/Social Computing
week 5	Social Computing
week 6	Human-Centered AI / Software Tools
week 7	Content creation / Visualization
week 8	Cognition / Methodology
week 9	Mental Health (TBD*) / Accessibility
week 10	ICT4D / Algorithm auditing
week 11	Ed tech / critical computing
week 12	Tools for thought / HRI (TBD)
week 13	Usable security (TBD) / Tech & Policy (TBD)
week 14-15	Data + HCI (TBD) / Student presentations**

How this class works

Class activity 1 of 4: Readings

Yes, you are reading in a Computer Science class.

There will be two papers to read for each class day.

This will take substantial time. It will get faster as the course proceeds and you get more used to reading papers.

Commentaries

After reading the papers for each class, you will reflect on the main ideas in each paper and submit a written commentary.

These commentaries serve as a mechanism to drive deeper reflection on the concepts in each paper.

Commentaries are **due at 11:59pm the day before lecture**.

We will drop the four lowest commentary grades at the end of class: meaning, you may drop four readings' worth of commentaries

Do's: writing a strong commentary

Do: engage with the core contributions —

Step 1 (Reflection): State the main point but then **reflect on why the ideas in the reading made sense from the authors' perspectives.**

Step 2 (Synthesis): How effectively does it convince you of that argument? **How could the argument be even more persuasive, on its own terms?**

Step 3 (Future work): What are the implications of the argument? **Given the ideas presented in the paper, what would you want to work on, or how would you modify those ideas?**

Don’ts: writing a strong commentary

Do not: stop after just disagreeing with what the authors wrote

Step 1 (Reflection): We get lots of commentaries that are mostly summary. Don’t stop here. We’ve all read the paper. 1–2 sentences max.

Step 2 (Synthesis): It’s easy to just lob criticisms and negativity. Too many commentaries are just lists of complaints. Instead, focus on: what’s at the core of this idea, and why is it holding sway? What might be a better version of this idea, if you’re unconvinced?

Step 3 (Future work): Too few commentaries cover this! Instead, ask yourself: what are applications of these ideas, and what follow-up ideas might be worth exploring?

~~“This paper has so many problems:”~~

“This paper inspired me to develop an idea:”

Example Length

I enjoyed learning about how the researchers used different approaches and compared-and-contrasted them in order to see how various tools categorized the importance of different graphical sections. I was most interested by the difference between Ground Truth BubbleView clicks and Predicted Importance projections. Specifically, I thought it was interesting that many of these graphics were magazine-esque layouts, with background images that projected the theme, but often didn't have super specific information, and large amounts of text in various sizes, colors, and placements. With BubbleView, it seemed that lots of people would click on the text, as well as these background images, but Predicted Importance often thought that the background image wasn't too important. I though this finding reiterated how important it is to choose background images that are intentional, and not just filler images to make the page important. If people's attention goes there more than we'd expect, it's crucial to spend time choosing images that accentuate your points rather than distract the reader.

One experience this reminded me of is other AI tools and algorithms that I have seen on social media sites, specifically those that try to decide the important areas of an image that should be showcased when cropped. Specifically, I remember similar cropping / importance algorithms being used on Twitter / X. However, these tools turned out to be extremely problematic, often cropping the images to focus on those who are white, thin, and female. Many articles dived into understanding this, and users themselves tested by adding photos with underrepresented populations vs. more privileged groups and saw the ethical issues themselves. Many tech people wrote articles (ex. Twitter's Photo-Cropping Algorithm Favors Young, Thin Females Links to an external site.), as well as Twitter themselves (Sharing learnings about our image cropping algorithm Links to an external site.). The biases present in this algorithm were deeply connected to general biases in AI, and I would have loved to see the article dive into that possibility more. They do not touch on any biases in their training data, or any edge cases they see that might need further exploration.

Overall, I felt that future work for this article relies on more than just making the tool open source for people to explore themselves. Certain fonts, text patterns, and images grabbed the attention of the user greatly, and a guide to those recommendations would make these learnings even more applicable to the average designer. Although these guides of design tips may exist now, I am sure that at the time of the release of this article, these suggestions would have really changed how people presented media online.

First readings for Tuesday

The Computer for the 21st Century

Specialized elements of hardware and software, connected by wires, radio waves and infrared, will be so ubiquitous that no one will notice their presence

by Mark Weiser

The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it.

Consider writing, perhaps the first information technology. The ability to represent spoken language symbolically for long-term storage freed information from the limits of individual memory. Today this technology is ubiquitous in countries. Not

is approachable only through complex jargon that has nothing to do with the tasks for which people use computers. The state of the art is perhaps analogous to the period when scribes had to know as much about making ink or baking clay as they did about writing.

The arcane aura that surrounds personal computers is not just a "user interface" problem. My colleagues and I at the Xerox Palo Alto Research Center think that the idea of a "personal" computer itself is misplaced and that the vision of laptop machines, dynabooks and knowledge navigators" is only a step toward achieving the

The idea of integrating computers seamlessly into the world at large runs counter to a number of present-day trends. "Ubiquitous computing" in this context does not mean just computers that can be carried to the beach, junnotebook computer, with access to a worldwide information network, still focuses attention on a single box. By analogy with writing, carrying a superlaptop is like owning just one very important book. Customizing this book, even writing millions of other books, does not begin to capture the real power of literacy.

Furthermore, although ubiquitous computers may use sound and vide in addition to text and graphics, make them "multimedia

PAPERS

Tangible Bits: Towards Seamless Interfaces between People, Bits and Atoms

CHI 97 * 22-27 March 1997

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ABSTRACT

This paper presents our vision of Human Computer Interaction (HCI): "Tangible Bits." Tangible Bits allows users to "grasp & manipulate" bits in the center of users' attention by coupling the bits with everyday physical objects and architectural surfaces. Tangible Bits also enables users to be aware of background bits at the periphery of human perception using ambient display media such as light, sound, airflow, and water movement in an augmented space. The goal of Tangible Bits is to bridge the gaps between both cyberspace and the physical environment, as well as the foreground and background of human activities.

This paper describes three key concepts of Tangible Bits: interactive surfaces; the coupling of bits with graspable physical objects; and ambient media for background awareness. We illustrate these concepts with three prototype systems – the metaDESK, transBOARD and ambientROOM – to identify underlying research issues.

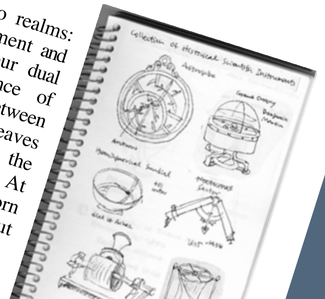
Keywords

tangible user interface, ambi
interface, augmented re
and periphery

BITS & ATOMS

We live between two realms: our physical environment and cyberspace. Despite our dual citizenship, the absence of seamless couplings between these parallel existences leaves a great divide between the worlds of bits and atoms. At the present, we are torn between these parallel but disjoint spaces.

We are now almost constantly "wired" so that we can be her (physical space) (cyberspace)



Class activity 2 of 4: In-Class Engagement

For the time being, we have opted to not have scheduled discussion sections but you need to be actively engaged.*

Ask questions during class. Engage with the questions. We want to see that you've carefully processed the readings and have come ready to construct durable, nuanced knowledge with the class.

Class activity 3 of 4: Quizzes

Four in-class quizzes

Cover the lecture content, every two weeks

- Each quiz will cover content spanning from the lecture day of the previous quiz up until, but not including, the current quiz's day
- e.g., Quiz 1, at the start of Week 3, will cover today through the last lecture of Week 2
- e.g., Quiz 2, at the end of Week 4, will cover the lectures from the same day as Quiz 1, through the first lecture of Week 4

Comprehensive final exam during our final exam slot

Closed-book, will ask you to recognize and apply the concepts from lecture

Quiz Timeline

week 1	
week 2	
week 3	Quiz (start of week)
week 4	Quiz (end of week)
week 5	
week 6	
week 7	Quiz (start of week)
week 8	Quiz (end of week)
week 9	
week 10	
week 11	
week 12.	Quiz (start of week)
week 13	
week 14	
week 15	
finals	Final

Class activity 4 of 4: Presentations

At the end of the semester, you all will give presentations on HCI topics of your interest. We expect you to take the same level of care and preparation into your presentations as we do into ours.

Prereqs and background

Most important: are you prepared to dive deep into foundational HCI theories and critique/discuss them?

Helpful:

- Depth in at least one of {computer science, social science methods, design, STS}
- Experience in human-computer interaction (e.g., CS 4120/5120)

Required:

- PhD or other programs: no prereqs
- Others: instructor approval (fill out today's questionnaire)

Grading

30% Paper commentaries

40% Four quizzes, 10% each

20% Final

5% In-class participation

5% Presentation

AI Usage Policy

Use of AI is **strictly regulated**. Reading responses must reflect your own human, complete, deep reading of the material. You must read all assigned readings in full yourself in full, you must write all responses yourself, and your responses must reflect opinions and arguments that are fully your own creation.

In other words, do reading responses according as if we were living in a pre-2022 world.

Outside of these restrictions, AI use is permitted (for instance, as a study aide). Ask if you want to use AI to support your learning in other ways.

Attendance Policy

Attendance and active participation are critical.

All students can miss up to two lectures for any reason (e.g., illness, interviews, conflicts) without penalty.

Any missed beyond two will count against the attendance and participation grade.

Credit for attendance = arriving on time, before lecture starts (Andrew is frustratingly consistent with starting on time)

Contact us

Questions: Post on Ed

* About material, policies, expectations -> public (non-anonymous please)

* Of personal nature -> private post to instructors

Readings, policies: https://penn-hci.github.io/cis7000-sp26/

Assignment submission: canvas.upenn.edu

Exit ticket

Everyone need to fill this out.

For those on the waitlist, your responses to this questionnaire can meaningfully affect your chances of being given permission to enroll.

https://bit.ly/hci-ff-day1

Questions?

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