

# **Building Interactive Systems**

# **Context-Aware Interaction**

**Professor Bilge Mutlu | Spring 2023**

# What will we cover today?

- Recap of context (from Week 03)
- History of context-aware computing
- Context-aware computing today

# Recap from Week 03: Sensing

# What is **context**?

**Definition:** Context is any information that can be used to characterise the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves.<sup>1</sup>

<sup>1</sup> Dey (2001). Understanding and using context. *Personal and ubiquitous computing*.

# Basic building blocks of context:<sup>2</sup>

1. running on a specific device (e.g. input system, screen size, network access, portability, etc.)
2. at a certain time (absolute time, e.g. 9:34 pro; class of time, e.g. in the morning)
3. used by one or more users (concurrently or sequentially)
4. in a certain physical environment (absolute location, type of location, conditions such as light, audio, and temperature, infrastructure, etc.)
5. in a social setting (people colocated and social role)
6. to solve a particular task (single task, group of tasks, or a general goal)

<sup>2</sup>Schmidt (2000). Implicit human computer interaction through context. *Personal technologies*.

# What is a **context-aware** system?

**Definition:** A system is context-aware if it uses context to provide relevant information and/or services to the user, where relevancy depends on the user's task.<sup>1</sup>

- Key to context-aware systems is the **situation** abstraction.
- The goal is "applications that do the right thing at the right time for users."<sup>1</sup>
- Key to building context-aware systems is **sensing**.

<sup>1</sup>Dey (2001). Understanding and using context. *Personal and ubiquitous computing*.

# Challenges in context awareness<sup>2</sup>

- What happens around an application while the application is in use? Are there any changes at all? → **Presence of changes**
- Do the surroundings (behaviour, environment, circumstances) carry any valuable information? Does it matter for the application? → **Availability Information**
- Is capturing and extracting the information feasible, acceptable for the application or device (processing cost, sensor cost, weight, etc.)? → **Capturing information**
- How to understand the information? What interpretation and reasoning is possible, useful? What reaction is appropriate for the application? → **Interpreting information**

<sup>2</sup>Schmidt (2000). Implicit human computer interaction through context. *Personal technologies*.

# How do we build context-aware systems?

A simple template: When **[context/situation]** take **[action]**

Examples:

- When **[I get home]**, **[remind me to take the trash out]**
- When **[chance of rain is 50%+]**, **[remind me take an umbrella]**
- When **[the delivery arrives]**, **[open door to accept delivery]**
- When **[the whole family arrives]**, **[play Christmas album]**
- When **[I get home from the grocery store]**, **[help me unload the groceries]**



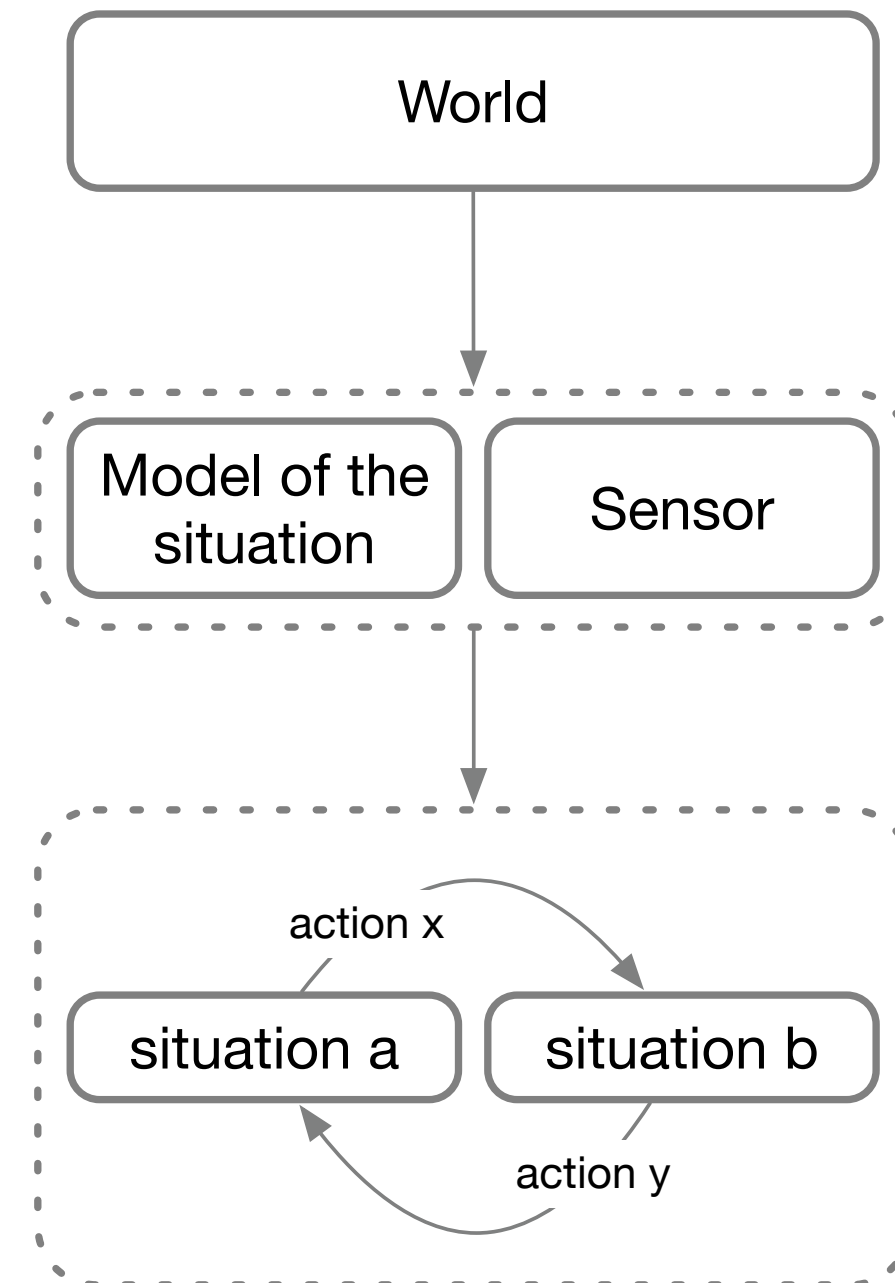
# How do we **sense** situations?

The simple template:

When **[context/situation]** take **[action]**

Extended version:

When **[situation]** changes from **[situation\_a]** to **[situation b]**, captured by **[sensor]**, take **[action]**



# How do we **model** situations?

Common elements (a consolidated version of Schmidt's building blocks):<sup>2</sup>

- **Time/place:** Occurring at a certain time, in a certain place, under certain circumstances
- **People:** Involving a certain user or a social setting
- **Task:** Targeting a task or a goal

<sup>2</sup>Schmidt (2000). Implicit human computer interaction through context. *Personal technologies*.

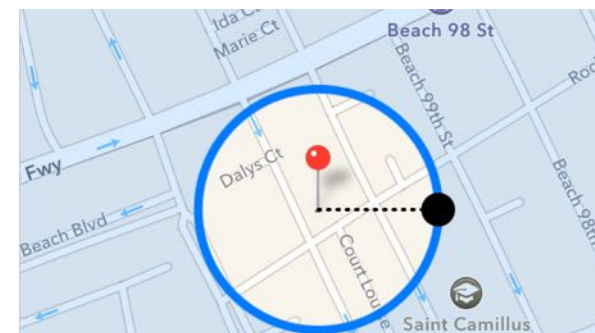
## When **[I get home]**, **[remind me to take the trash out]**

1. Time/place: (arrival at) home
2. People: main user
3. Task: trigger action

1. Time/place:  
location[home, ...]
2. People:  
user[main, ...]
3. Task:  
action[remind, ...]

Change/trigger:

location[not\_home] → location[home]



# How to determine **change**?

Potential triggers:

- Enter a context
- Leave a context
- While in a context

Potential triggers:

- `situation[not_a] → situation[a]`
- `situation[a] → situation[not_a]`
- `situation[a]`

**Where does context-awareness come from?**



# Ubiquitous Computing

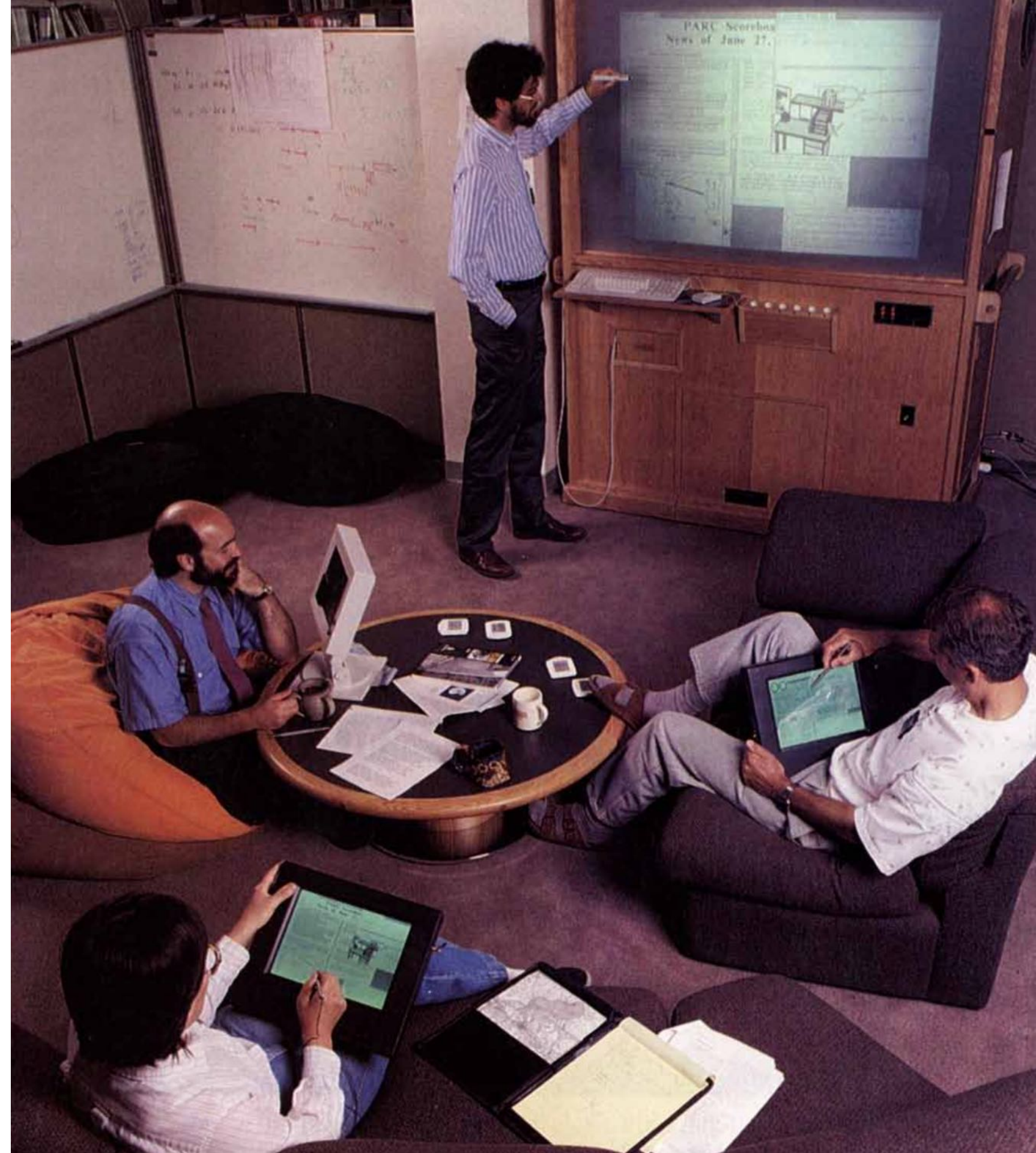
Ubiquitous computing (aka ubicomp) is the concept of using small internet connected and inexpensive computers to help with everyday functions in an automated fashion.<sup>3</sup>

The Computer for the 21st Century *by Mark Weiser*<sup>4</sup>

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

<sup>3</sup> [Wikipedia: Ubiquitous Computing](#)

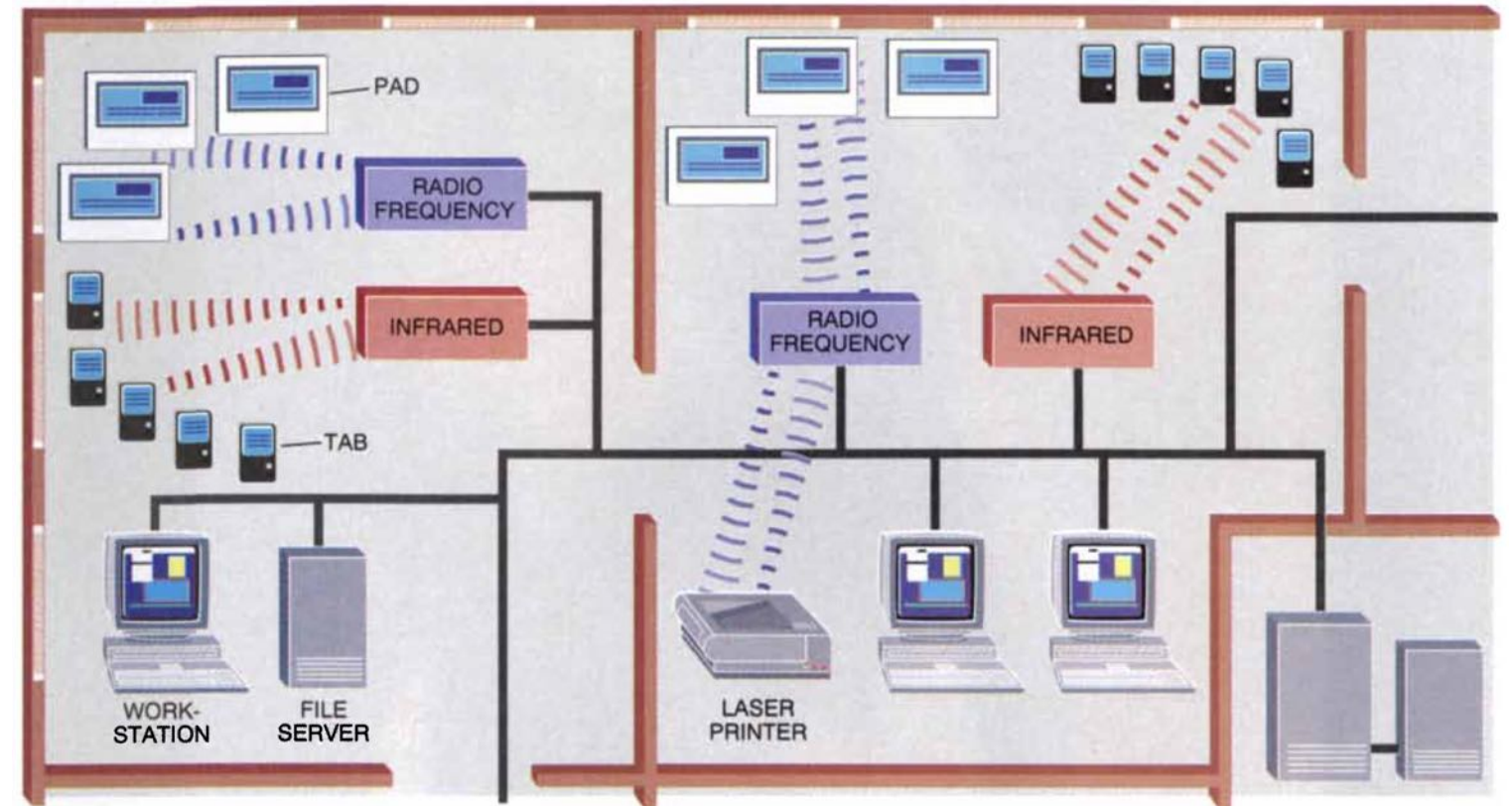
<sup>4</sup> Weiser (1991). [The Computer for the 21 st Century](#). *Scientific american*.





# Core Ideas from Weiser's Vision

- Computers should disappear in the background
- The use of computers should be unconscious
- Ecology of specialized devices to tasks at different scale
  - Tabs, page, boards<sup>4</sup>



<sup>4</sup>Weiser (1991). The Computer for the 21 st Century. *Scientific american*.





<sup>5</sup> Image



# What does ubicomp mean for systems?

Notable characteristics:

- Edge computing (early IoT)<sup>6</sup>
- Automated personalization
- Adaptation to situations/context

<sup>6</sup> Computing closer to the activity or source of data.

## The Active

This harbinger of inch-scale computers contains a small microprocessor and an infrared transmitter. The badge broadcasts the identity of its wearer and so can trigger automatic doors, automatic telephone forwarding and computer displays customized to each person reading them. The active badge and other networked tiny computers are called tabs.



# Ubicomp in the Home

**Unremarkable Computing:** Designing technology to blend into day-to-day routines, to become "invisible in use," to become "unremarkable."<sup>7</sup>

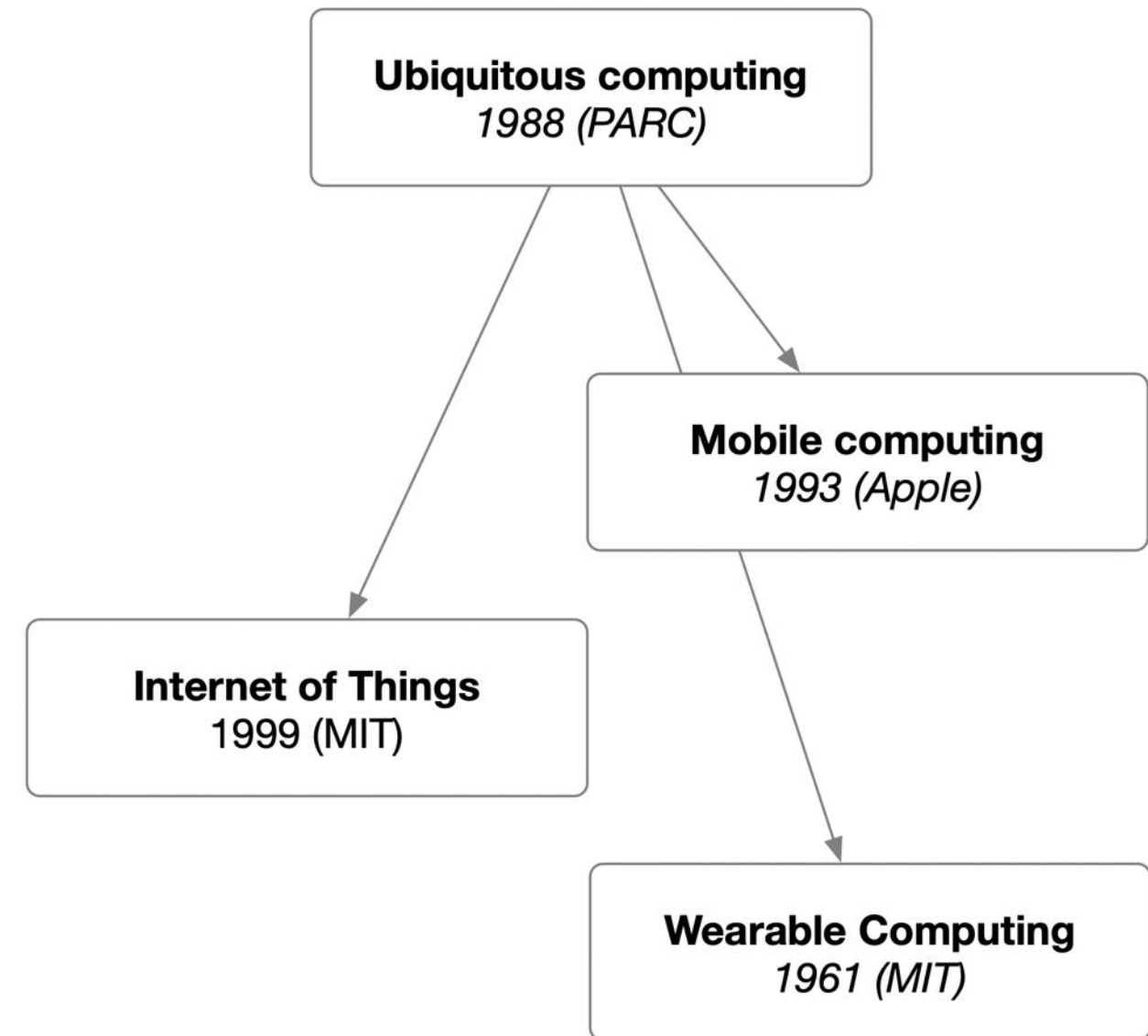
How do we design technological support for existing routines such that the technology itself becomes unremarkable?

<sup>7</sup>Tolmie et al. (2002). Unremarkable computing. *CHI 2002*.

# Ubiquitous Computing: Past and Present

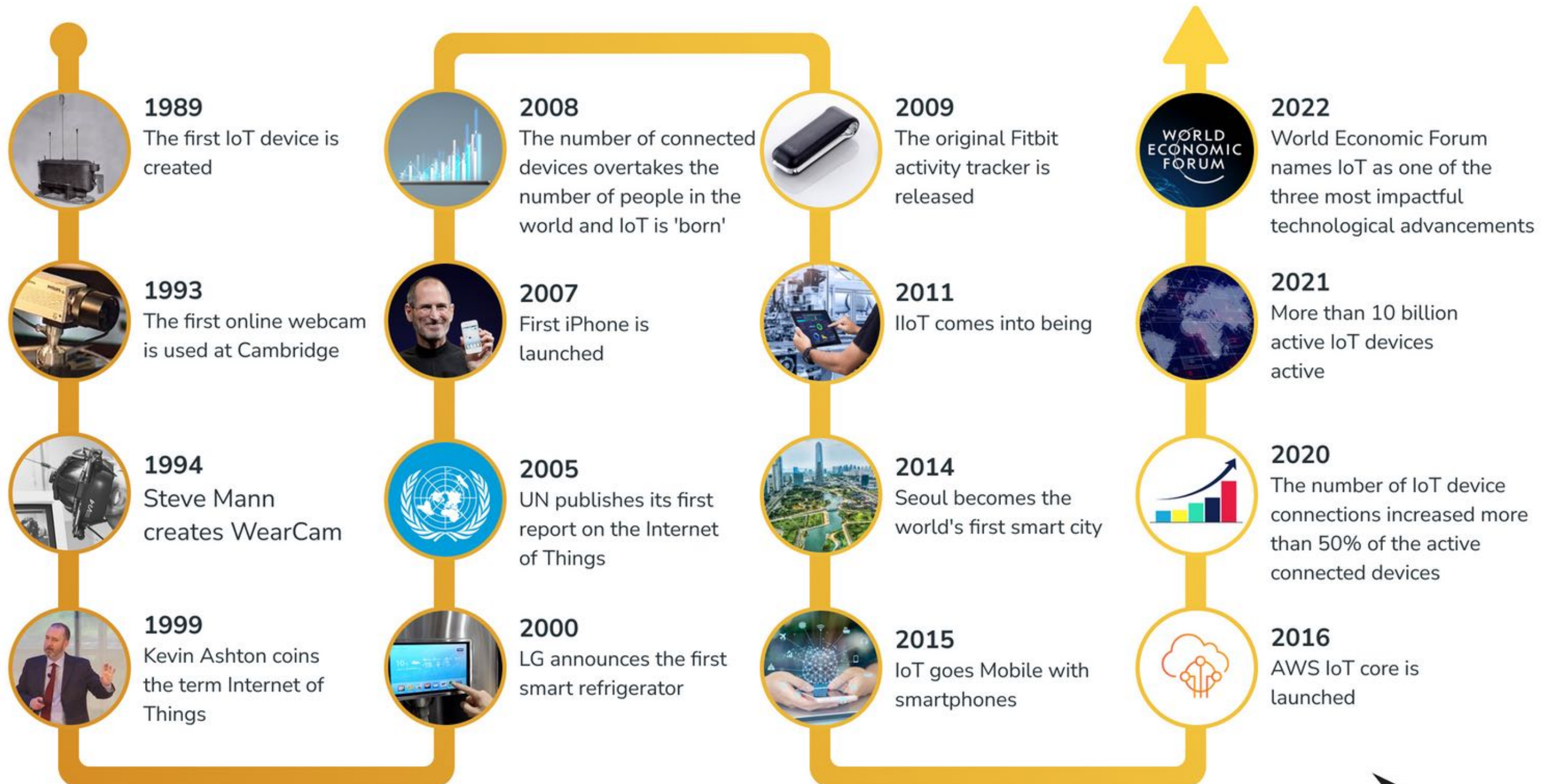
Relevant paradigms:<sup>8</sup>

- Ubicomp (1998, PARC)
- Mobile computing (1993, Apple)
- Internet of Things (1999, MIT)
- Wearable computing (1961, MIT)



<sup>8</sup> History: [Ubicomp](#), [Mobile Computing](#), [IoT](#), [Wearable technology](#)





<sup>9</sup> Image

# Context-Aware Computing Today

# Operationalization of Context Awareness

Let's examine how context-awareness is operationalized across related areas:

- Ubicomp
- Mobile computing
- Wearable computing
- IoT

# Operationalization of Context Awareness:

## Ubicomp<sup>10</sup>

What does **context** mean?

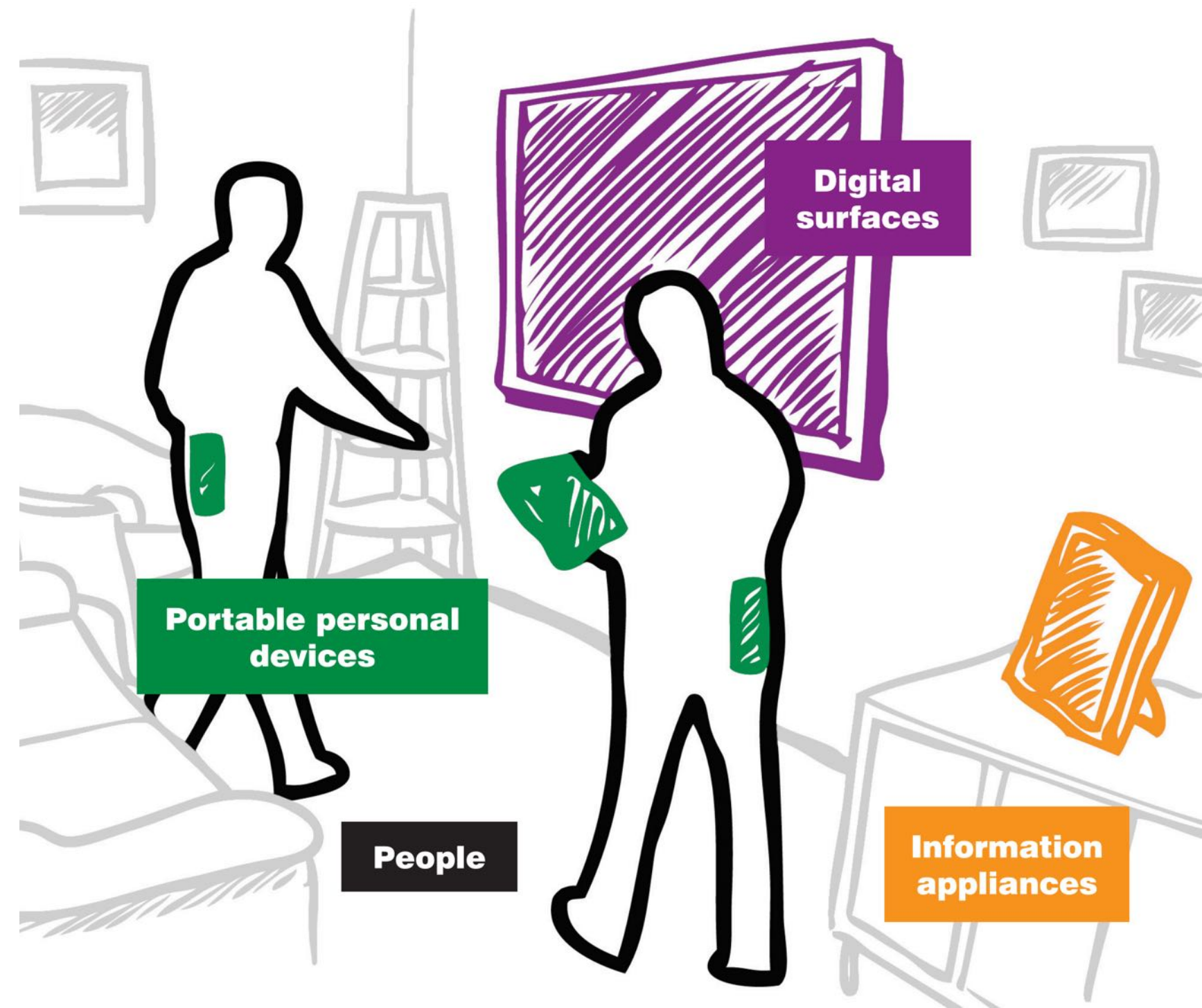
→ User activity, intent

How is context modeled/captured?

→ Different configurations of gaze, orientation, proximity and device use signaling different activities/intent. Sensing through environmental sensors, specialized devices

What does **context-awareness** mean?

→ Seamless support for shifting contexts



<sup>10</sup>Greenberg et al. (2011). *Proxemic interactions: the new ubicomp? interactions*.



# Operationalization of Context Awareness:

## Ubicomp<sup>11</sup>

What does **context** mean?

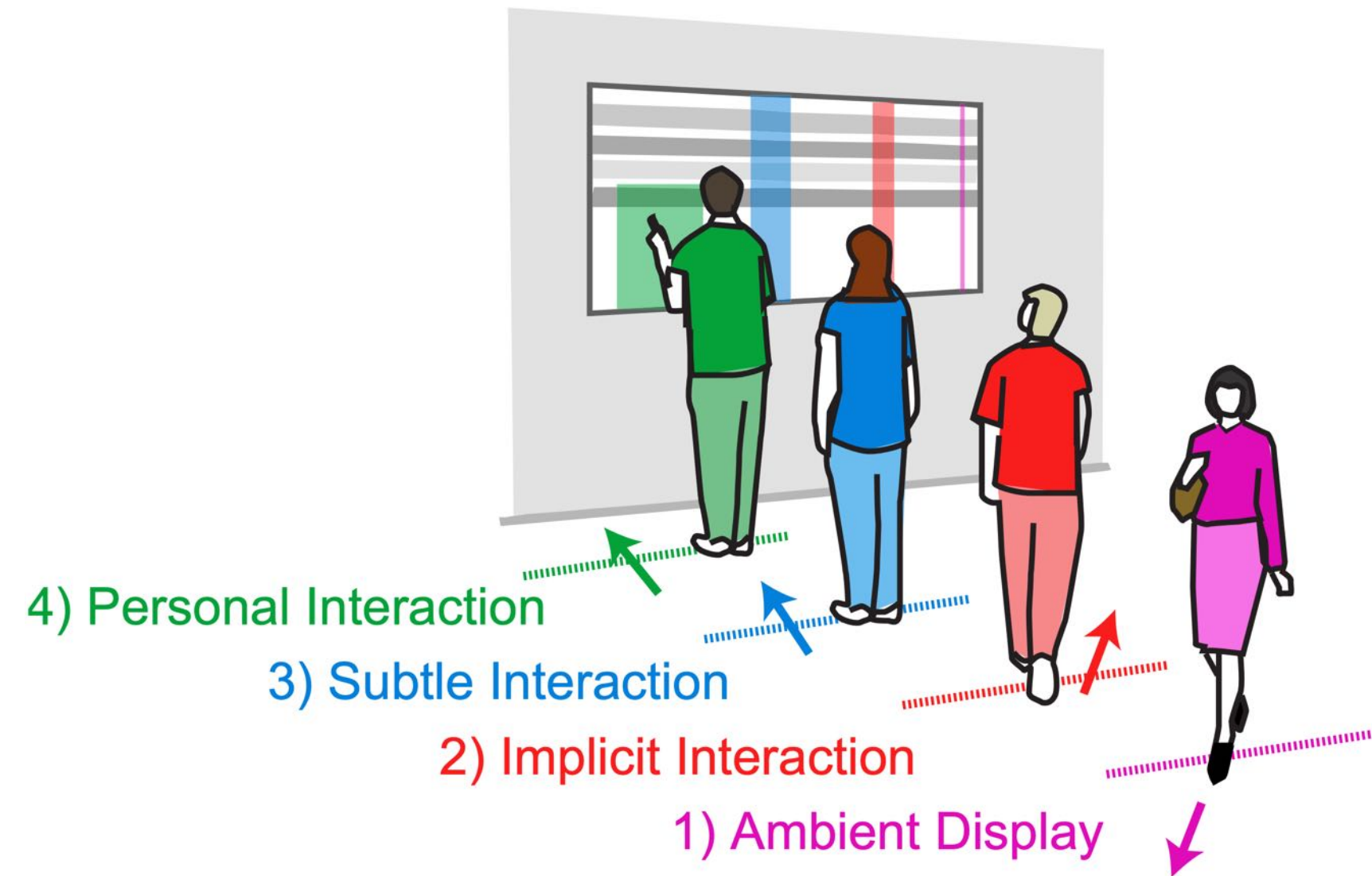
→ User activity, intent

How is context modeled/captured?

→ Modeled as different levels of proximity signaling different intent. Sensing through environmental sensors.

What does **context-awareness** mean?

→ Seamless support for shifting contexts



<sup>11</sup>Vogel & Balakrishnan (2004). Interactive public ambient displays: transitioning from implicit to explicit, public to personal, interaction with multiple users. *UIST 2004.*



# Operationalization...: **Mobile Computing**<sup>12 13</sup>

What does **context** mean?

→ User activity, inferred from location

How is context modeled/captured?

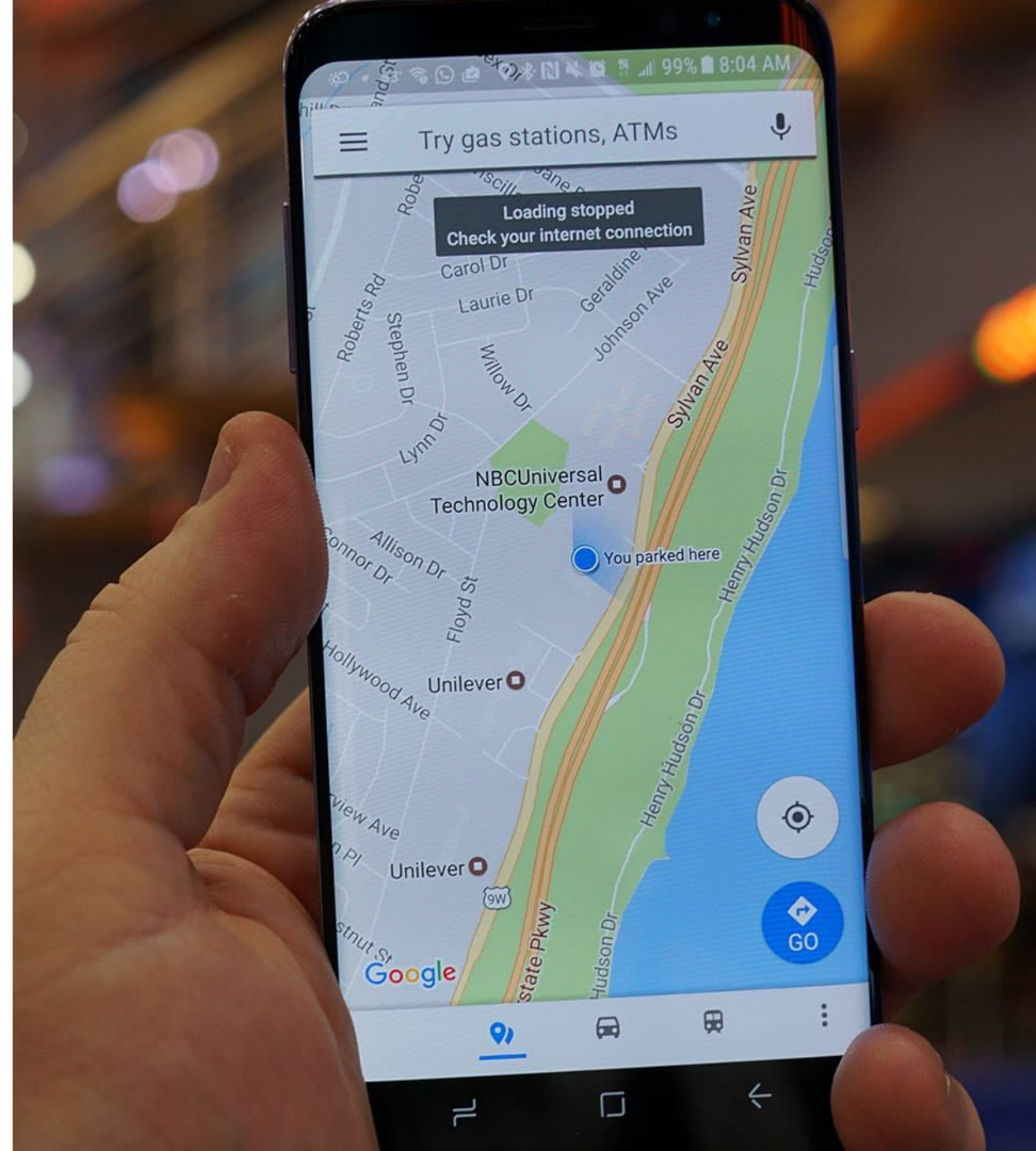
→ Location, proximity to other systems signal context, captured through device sensors.

What does **context-awareness** mean?

→ Present information and services; automatically perform a service; tag information for later retrieval

<sup>12</sup> Dey & Häkkinen (2008). *Context-awareness and mobile devices*. In *Handbook of research on user interface design and evaluation for mobile technology*.

<sup>13</sup> [Image](#)



# Operationalization...: **Mobile Computing**<sup>12</sup>

Some challenges:

- Developers have little experience with defining/modeling/capturing/infering/adapting to context.
- Abstractions, rather than raw sensor data, might be more useful.
- Data must be fused to recognize context. Requires handling uncertainty.
- Applications must adapt to dynamic changes in context.

<sup>12</sup> Dey & Häkkinen (2008). Context-awareness and mobile devices. In *Handbook of research on user interface design and evaluation for mobile technology*.



# Operationalization of Context Awareness: **Wearable Computing**<sup>14</sup>



<sup>14</sup> Laput & Harrison (2019). Sensing Fine-Grained Hand Activity with Smartwatches CHI 2019.

# Operationalization of Context Awareness: **Wearable Computing**<sup>14</sup>

What does **context** mean?

→ User activity

How is context modeled/captured?

→ Unique signals from multitude of sensors on a wearable device.

What does **context-awareness** mean?

→ Activity support

<sup>14</sup> Laput & Harrison (2019). Sensing Fine-Grained Hand Activity with Smartwatches *CHI 2019*.



# Operationalization of Context Awareness: IoT<sup>15</sup>

What does **context** mean?

→ User intent, states

How is context modeled/captured?

→ Discrete user states, parameters from sparse device input and/or sensing.

What does **context-awareness** mean?

→ Adapting to user preferences; identifying user states to offer services; correct identification

<sup>15</sup> [Image](#)



# What did we cover today?

- Recap of context (from Week 03)
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- Context-aware computing today