Location & Mobility

Arthur Tham - March 1st, 2021
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Framing Paper: Location Systems for Ubiquitous Computing (2001)

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Engineering Manager at Google
Focus: Mobile computing systems
Previously:

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Focus: Networking devices
Previously:

- PhD, CS from Cal Berkeley
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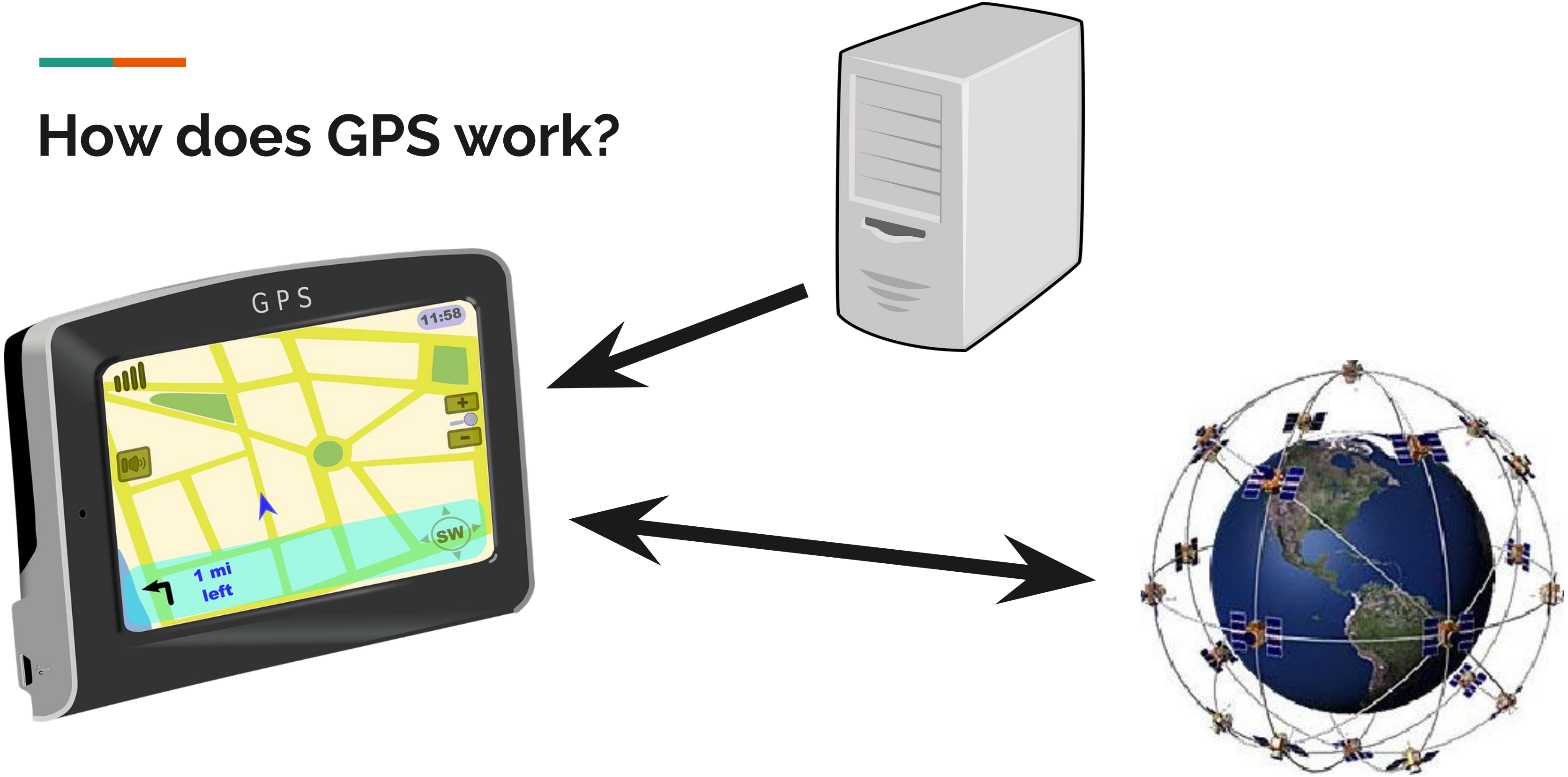
The Most Popular Location Device in 2001

- Garmin's **Global Positioning Systems** are the most iconic devices at the time
- Physical positioning (latitude/longitude)
- Is it reliable?

How does GPS work?



Techniques/Types of Location Sensing

Techniques

1. **Triangulation**
   a. **Lateration** (distances from multiple known points)
   b. **Angulation** (relative to points with known location, like a scale)
2. **Proximity** from a known set of points
3. **Scene Analysis,** view from a vantage point

Types

1. **Physical Location**, where you are
2. **Symbolic Location**, proximity to known objects

Systems

1. **Absolute**, shared reference grid (GPS)
2. **Relative**, each object has its own reference

Improvements to Technology

- Is it **accurate**? (Measurement range in distance units)
- Is it **precise**? (Percentage of good accuracy)
- Is it **scalable**?
- How good is its **recognition**?
- Is it **cost-efficient**?
- Are there **limitations** such as signal loss?

Survey of Location Devices in 2001

Table 1. Current location sensing technologies.

Technology	Technique	Physical	Symbolic	Absolute	Relative	LLC	Recognition	Accuracy and precision if available	Scale	Cost	Limitations
GPS	Radio time-of-flight lateration	•		•		✓		1-5 meters (95-99 percent)	24 satellites worldwide	Expensive infrastructure $100 receivers	Not indoors
Active Badges	Diffuse infrared cellular proximity		•	•			✓	Room size	1 base per room, badge per base per 10 sec	Administration costs, cheap tags and bases	Sunlight and fluorescent light interfere with infrared
Active Bats	Ultrasound time-of-flight lateration	•		•			✓	9 cm (95 percent)	1 base per 10 square meters, 25 computations per room per sec	Administration costs, cheap tags and sensors	Required ceiling sensor grid
MotionStar	Scene analysis, lateration	•		•			✓	1 mm, 1 ms, 0.1° (nearly 100 percent)	Controller per scene, 108 sensors per scene	Controlled scenes, expensive hardware	Control unit tether, precise installation
VHF Omni-directional Ranging	Angulation	•		•		✓		1° radial (≈ 100 percent)	Several transmitters per metropolitan area	Expensive infrastructure, inexpensive aircraft receivers	30-140 nautical miles, line of sight
Cricket	Proximity, lateration		•	∘	∘	✓		4 × 4 ft. regions	≈ 1 beacon per 16	$10 beacons and receivers	No central management

Sur

Ranging									area	aircraft receivers	
Cricket	Proximity, lateration		•	∘	∘	✓		4 × 4 ft. regions (≈ 100 percent)	≈ 1 beacon per 16 square ft.	$10 beacons and receivers	No central management receiver computation
MSR RADAR	802.11 RF scene analysis and triangulation	•		•			✓	3-4.3 m (50 percent)	3 bases per floor	802.11 network installation, ≈ $100 wireless NICs	Wireless NICs required
PinPoint 3D-iD	RF lateration	•		•			✓	1-3 m	Several bases per building	Infrastructure installation, expensive hardware	Proprietary, 802.11 interference
Avalanche Transceivers	Radio signal strength proximity	•			•			Variable, 60-80 meter range	1 transceiver per person	≈ $200 per transceiver	Short radio range, unwanted signal attenuation
Easy Living	Vision, triangulation		•	•			✓	Variable	3 cameras per small room	Processing power, install-ation cameras	Ubiquitous public cameras
Smart Floor	Physical contact proximity	•		•			✓	Spacing of pressure sensors (100 percent)	Complete sensor grid per floor	Installation of sensor grid, creation of footfall training dataset	Recognition may not scale to large populations
Automatic ID systems	Proximity		•	∘	∘		✓	Range of sensing phenomenon (RFID typically <1m)	Sensor per location	Installation, variable hardware costs	Must know sensor locations
Wireless Andrew	802.11 proximity		•	•			✓	802.11 cell size, (≈ approx. 100 m indoor, 1 km free space)	Many bases per campus	802.11 deployment, ≈ $100 wireless NICs	Wireless NICs required, RF cell geometries
E911	Triangulation	•		•			✓	150-300 m (95 percent)	Density of cellular infrastructure	Upgrading phone hardware or cell infrastructure	Only where cell coverage exists
SpotON	Ad hoc lateration	•			•		✓	Depends on cluster size	Cluster at least 2 tags	$30 per tag, no infrastructure	Attenuation less accurate than time-of-flight

Survey of Location Devices in 2001

Techniques

- Radio time-of-flight lateration
- IR/Cellular
- Ultrasound
- Scene analysis
- Angulation
- Proximity
- 802.11 RF
- Vision
- Physical contact
- Adhoc networks
- ...

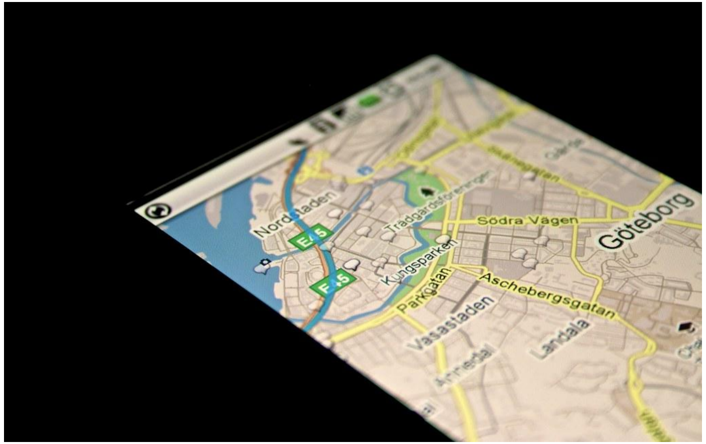
COST:

Varies

Location Devices in 2021

- Now, we can use **smartphones** as a GPS
- We can also look up information on the web for certain locations
- Harder to get lost unless we don't have cellular / data reception
- Potential applications: Tourism stuff like navigating places that you're unfamiliar with, or games like Pokemon Go

Google Maps



Survey of Location Devices: Slack Responses

Colby: I partly wonder if there is an updated equivalent to this article for location systems since the article was written in 2001, but at the same time it seems like the only new developments in location systems... is the broader inclusion of WiFi and Bluetooth in increasing location accuracy.

Dennis: I believe the systems sounds relatively more expensive because they were from almost twenty years ago when mobile device had far less capability than the devices today… They also did not include any example scenario/usage in the table, which I wish they did, because it is a bit hard to imagine how these technology applies to real context from today.

Survey of Location Devices: Slack Responses

Lika: Knowing the type of information a location system can provide is crucial to the design of applications. For example, a technology that locates an older adult may need to provide a physical position when the user is doing outdoor activity, and also provides a symbolic location when the user is indoors.

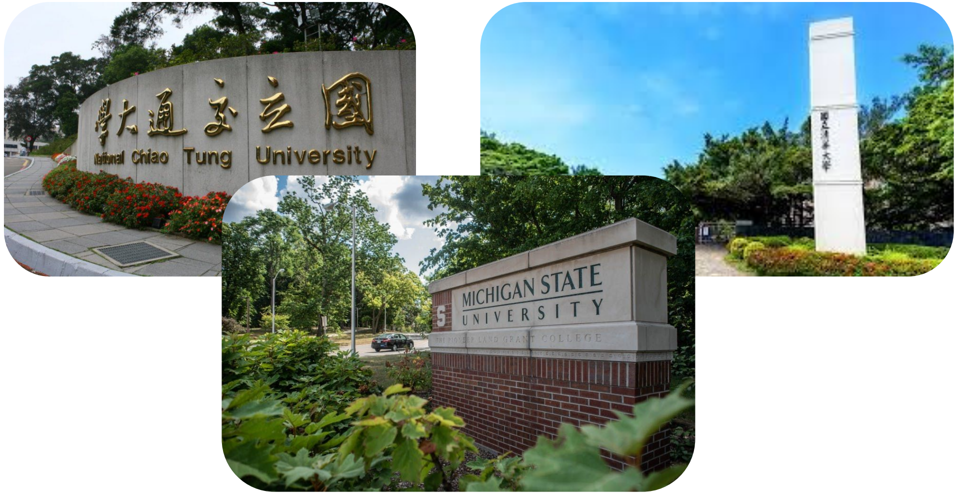
Myles: It is pretty hard to think that someone from 20 years ago had already thought these kinds of usages using location-sensing technology.

Discussion Question 1

Are dedicated location devices like GPS still useful and affordable in today's society (2021)?

- What are some use cases for these devices today?
- Are they worth the cost?
- Are smartphones our ultimate GPS/location device?

Recent Paper: Tourgether: Exploring Tourists’ Real-time Sharing of Experiences as a Means of Encouraging Point-of-Interest Exploration (2019)



Collaboration between members of:

- 國立交通大學Chiao Tung
- 國立清華大學Tsing Hua
- Michigan State University


A bunch of researchers in Taiwan
The one American person in Michigan

Recent Paper: Tourgether: Exploring Tourists' Real-time Sharing of Experiences as a Means of Encouraging Point-of-Interest Exploration (2019)

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Associate Professor, CS
Focus: HCI, UX
Previously:

- BS., CS from NCTU
- MS, PhD, U of Michigan
- Intern at Microsoft
- Research associate at U of Michigan
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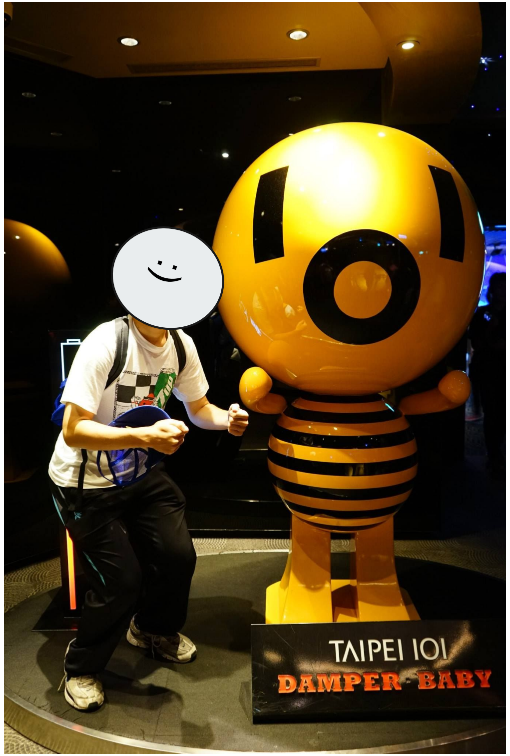
Tourgether

Enable tourists to share their experiences via check-in functionality

- Main focus on POIs, or points of interest (or lack thereof)
- Scope: Pedestrians in locations with many POIs
- Many types of users:
  - Use it as a planner to see POIs,
  - Use it as a logging tool,
  - Use it to YOLO yourself into a region



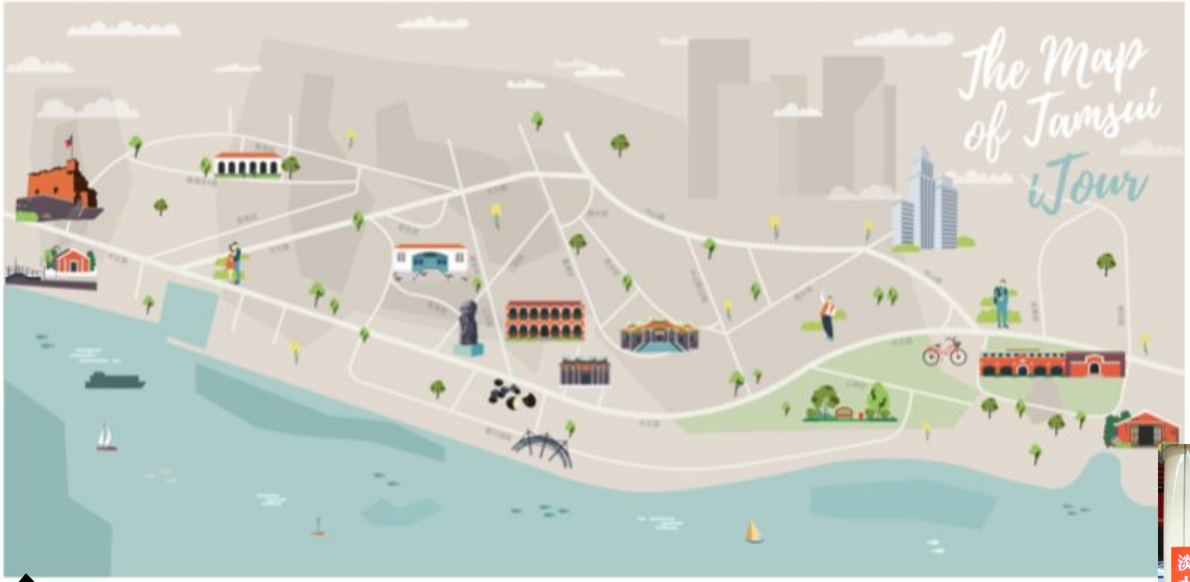
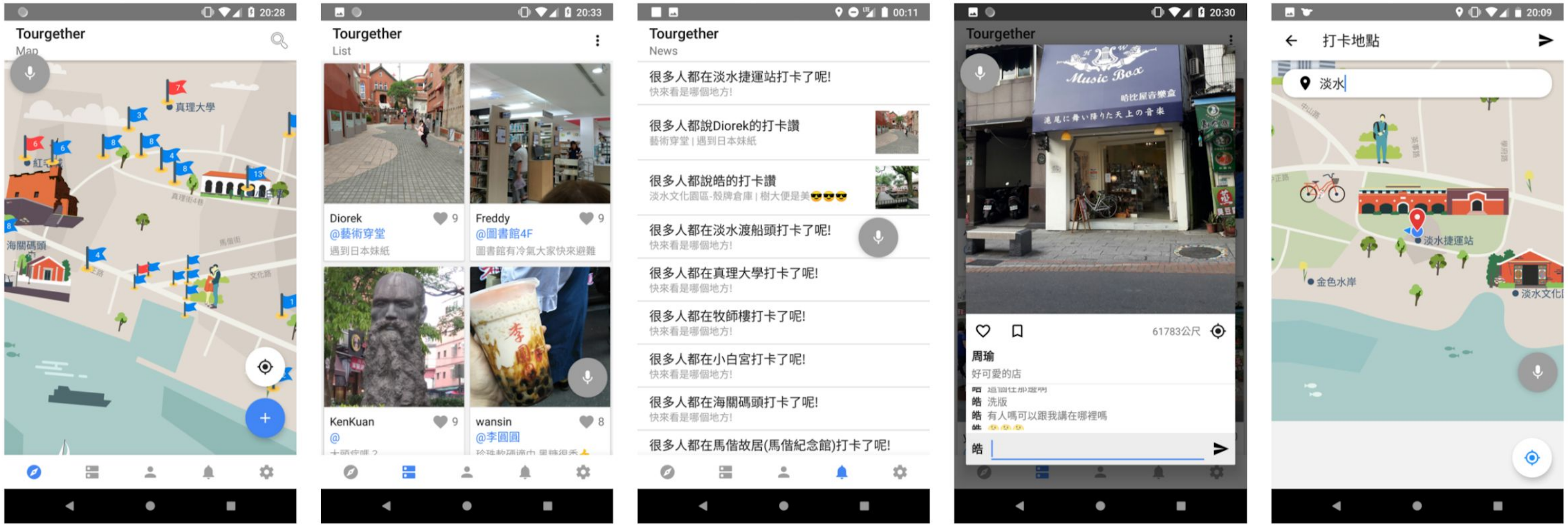


Fig. 1. Tourist map of Tamsui designed by the research team

淡水



(a) (b) (c) (d) (e)

Fig. 3. System design of Tourgether, including (a) its GPS-enabled Tourist Map displaying graphics of important POIs and displaying check-ins with flag icons; (b) its News Feed page presenting all user check-ins; (c) all received notifications, divided into three categories, i.e., the most-liked current check-ins, the most checked-in areas, and newly checked-in POIs that the user has never visited; (d) its check-in post interface, with like, save and locate buttons below the image; and (e) its page for choosing a location when posting a check-in.

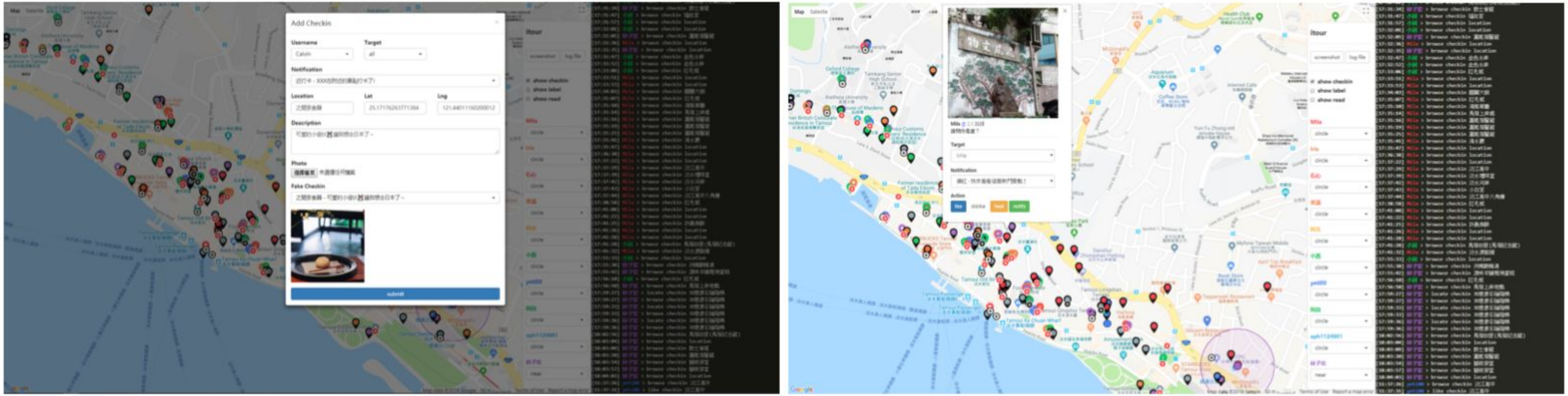


Fig. 2. Control panel for creating check-ins, delivery of notifications, monitoring of users' real-time GPS coordinates, and app usage log

Note the check in areas all over Tamsui

Tourgether: Slack Responses

Jo: I liked that the real-time sharing experiences created a feeling of co-presence while preserving privacy. However, I felt it was not clear if it can eventually help people explore various sites that are less well-known.

Neeraj: This mobile app will do well in the pandemic if for example 75 incoming UC Irvine students are given the app and can do a virtual tour real-time with others while being socially distanced. Might not even need tour guides at that point.

Jason: The authors mention the issue that common tourist maps and websites tend to only showcase the most popular POIs, but they also display the most popular ones on the map with an icon while displaying lesser-known ones with just their names. I feel that, like Jo mentioned, that this would further reinforce the existing popularity.

Discussion Question 2

Are check-in apps useful for:

- Active tourists that like to plan their routes, or
- Tourists that make up their plans on the fly, or
- Non-tourists that usually have no interest in tourism?

Discussion Question 3

How can we use technology to increase awareness of non-POIs?

- Are location applications only good for POI discovery and navigation?
- Can non-POIs really be discovered easily?

Security and Privacy

Both articles mention privacy in varying degrees

- Hightower and Borriello: implies there are privacy measures in place for location devices in 2001
    - What about in 2021?
- Chang et al: Tourgether gives an impression that user locations are not being tracked, compared to (very specifically) Facebook
    - Anonymous check-ins seems to help this perception in favor of Tourgether
    - Do they trust strangers in Tourgether over the friends they add on Facebook?

Security and Privacy: Slack Responses

Maruf: Although the paper was primarily focused on lowering cost, reducing technical requirements, improving scalability, I was wondering about the social implications of such technologies. In a world where surveillance of citizens by the establishment is becoming more and more prevalent, to what extent these applications protect users privacy. I think privacy and security are as important evaluation criteria as technical requirements.

Discussion Question 4

Can we have location-based apps and ensure privacy / prevention of location tracking?

- What are some approaches that we can apply (including existing implementations)?

Discussion Question 5

- Open Discussion