Mobility and Quality of Life among Wheelchair Users: A Study using Mobile Phone Data in South Korea

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Introduction

Limited Mobility among the Disabled

- The estimated number of disabled people was 2,668,411 (5.39% of total population) in Korea (KOSIS, 2018)

- Social policies towards social inclusion of the disabled
  - The Americans with Disabilities At (ADA) in the U.S. (1990, ADA Amendments Act of 2008)
  - The United Nation's the Convention on the Right of People with Disabilities (CRPD) (more than 180 countries have signed the UN CRPD)
  - The Act on the Prohibition of Discrimination against Persons with Disabilities and Remedies for Infringement of their Rights (2008)

- Korean society is still exclusive and discriminatory against the disabled
  - According to the 2014 National Survey of Disabled Persons in Korea, the second most reported reason why respondents could not go a hospital was limited mobility (15.2%) (followed after economic hardship, 58.8%).

Theoretical Background

- The Social Model of disability
  - Disability as a concept of impairments through the construction of social barriers.
  - It pays attention to the collective responsibility of society for the disabled.

- Mobilities Paradigm
  - A framework for interpreting and understanding social phenomena in terms of various mobilities

- The concept of Social Exclusion
  - Social exclusion as a multidimensional and dynamic concept of deprivation that goes beyond a description of poverty.

Literature Review

- Activity theory of subjective well-being explains that happiness and life satisfaction are the by-products of activities and social interaction (Diener, 1984).

- A lack of mobility, which limits resources and capital for social advantages, can lead to lower levels of subjective well-being through the risk of social exclusion and isolation (De Vries et al., 2012, Stanley et al., 2011, Velho et al., 2016).

Study Purpose

- The aims of this study
  - To explore mobilities among physically disabled wheelchair users
  - To determine if and how their mobilities are associated with life satisfaction.

- The significance of this study
  - Using integrated data from different data collection methodologies
    - Offline survey
    - Daily online surveys
    - GPS data from mobile phones

  - Focusing on multiple aspects of mobility
    - The frequency of movement (how often a person goes anywhere)
    - Spatial range (how far a person moves)
    - The variance of movement (how many different places a person visited or how many different paths a person travels)
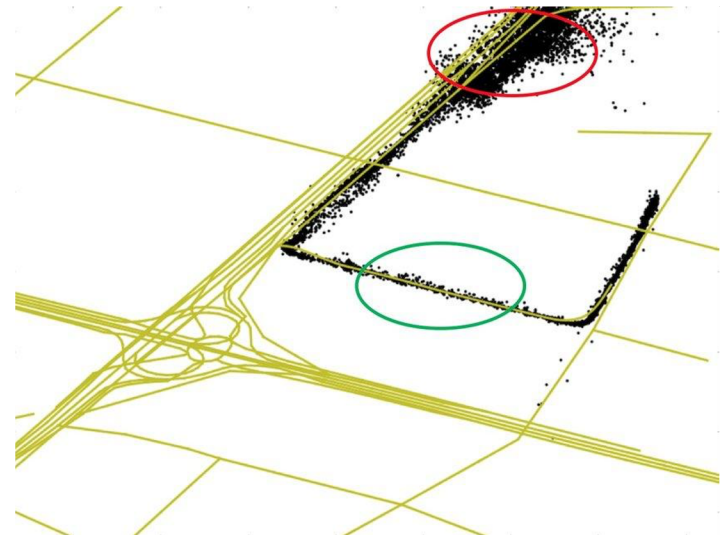
Methods

Human mobility sensing

Call Detail Record
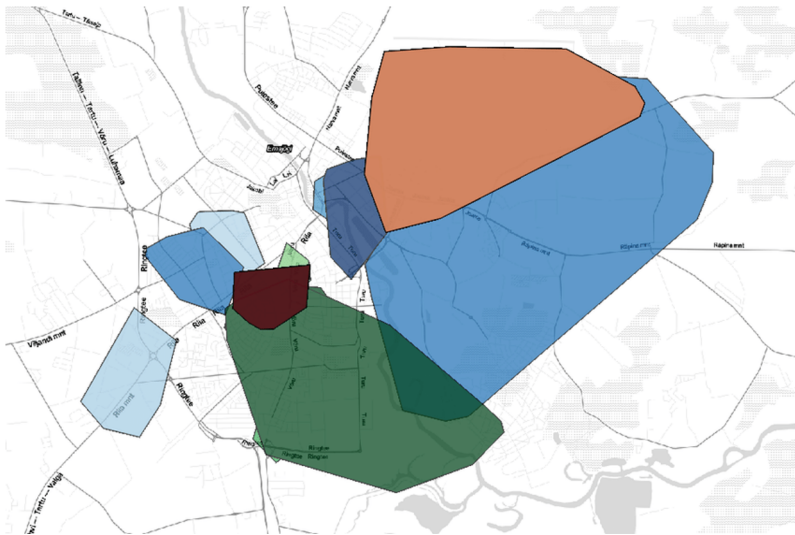
- Produced by a telephone exchange or other telecommunications equipment.
- Data: Call time, duration, source and destination numbers, etc.
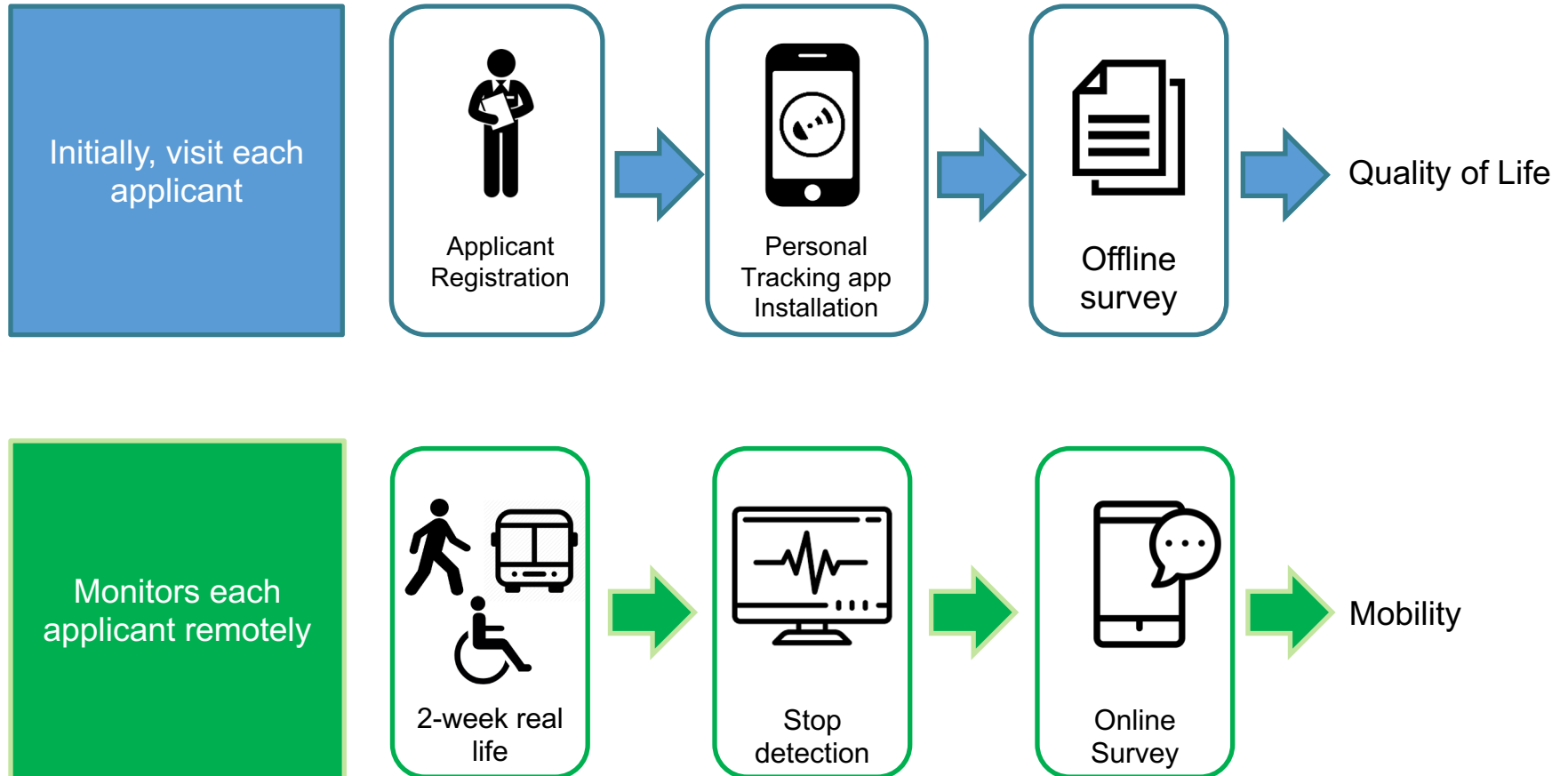- Easy to get massive amount of data, but not specific position.

GPS Trajectory

- Sequence of moving object with GPS Sensor.
- Data: Latitude, longitude, altitude, and time
- A separate sensor (GPS) is required, but most smartphones already have it.
- Very specific position on outdoor.

Mobility DB Creation Process

Initially, visit each applicant → Applicant Registration → Personal Tracking app Installation → Offline survey → Quality of Life

Monitors each applicant remotely → 2-week real life → Stop detection → Online Survey → Mobility

Offline Survey

- Questions about
  - Quality of life
  - Perceptions on their mobility behaviors
  - Social capital and social participation
  - Experience of social discrimination
  - The severity of disabilities
  - Most often used transportation mode
  - Number of trips (going out) per week
  - Socio-demographic characteristics (e.g., family income, age, gender, and so on)

※다음의 질문에 대해 해당되는 번호에 √표를 하여 주십시오.

1. 장애등록 여부 및 장애유형과 관계없이 귀하의 주된 장애는 무엇입니까? (※1가지만 선택하여 기입하시오)

1) 지체장애   2) 뇌병변장애   3) 시각장애   4) 청각장애
5) 언어장애   6) 지적장애   7) 자폐성장애   8) 정신장애
9) 신장장애   10) 심장장애   11) 호흡기장애   12) 간장애
13) 안면장애   14) 장루·요루장애   15) 뇌전증(간질)장애

2. 주된 장애를 최초로 알게 된(발견한) 것은 언제였습니까?

1) 출생전 또는 출생시
2) 돌 이전
3) 돌 이후 (구체적으로 몇 살 때입니까? 만_____세)

6. 귀하는 평소 어떤 이동보조기기를 사용하십니까?

1) 전동 휠체어(스쿠터)를 사용한다.   2) 수동 휠체어를 사용한다.   3) 사용하지 않는다.

6-1. (전동 혹은 수동)휠체어 세척/청소는 얼마에 한 번씩 하십니까?(※ 휠체어를 사용하지 않는다면 '해당 없음'을 선택하시오)

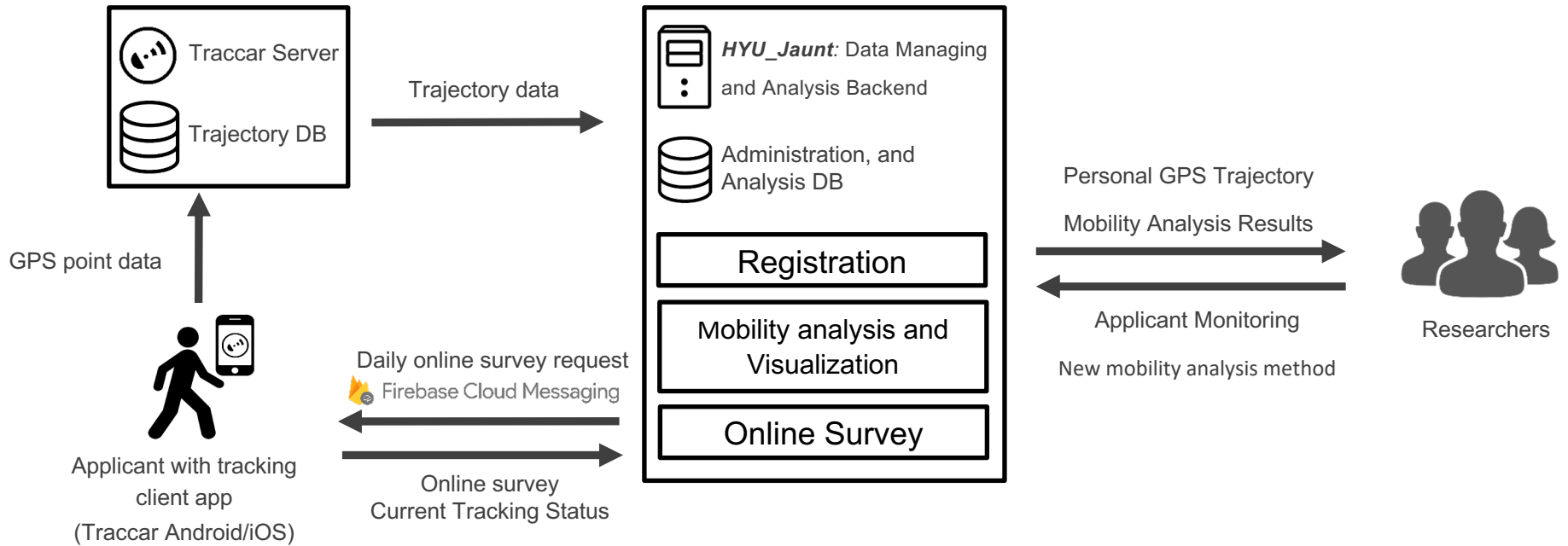1) 주 1회 이상   2) 월 2~3번   3) 년 2~3번   4) 하지 않음   5) 해당 없음

6-2. (전동 혹은 수동)휠체어 세척/청소는 주로 누가 하십니까?(※ 휠체어를 사용하지 않는다면 '해당없음'을 선택하시오)

1) 스스로   2) 가족   3) 활동보조사
4) 요양보호사   5) 하지 않음   6) 기타 (   )

6-3. (전동 혹은 수동) 휠체어의 고장을 경험한 적이 있습니까?(※ 휠체어를 사용하지 않을 경우 '해당 없음'을 선택하시오)

1) 있다.   2) 없다.   3) 해당 없음

Data Flow

Traccar Server

Trajectory DB

Trajectory data →

GPS point data ↑

Applicant with tracking
client app
(Traccar Android/iOS)

Daily online survey request
🔥 Firebase Cloud Messaging

Online survey
Current Tracking Status

HYU_Jaunt: Data Managing
and Analysis Backend

Administration, and
Analysis DB

Registration

Mobility analysis and
Visualization

Online Survey

Personal GPS Trajectory

Mobility Analysis Results →

← Applicant Monitoring

New mobility analysis method

Researchers

GPS Trajectories

– Collect location data of the participants using Smartphone GPS sensors

– Real-time monitoring via Traccar Server™ (Open-source GPS tracking platform)

  – 24/7 GPS location tracking on smartphone

  – Transmit location data at specified time interval. Mostly 60 sec.

  – Shorter intervals improve data quality, but increase battery consumption

| lat	lng	datetime	uid	speed	acceleration
37.546584	127.053889	2020-12-23 07:20:05	12	1.220095	0.040670
37.564592	127.029592	2020-12-23 09:22:48	12	0.000000	0.000000
37.564338	127.036069	2020-12-23 10:01:33	12	2.344292	0.078143
37.564324	127.036131	2020-12-24 08:35:49	12	0.477294	0.015397
37.564326	127.036167	2020-12-25 06:45:09	12	0.777947	0.025932

GPS points
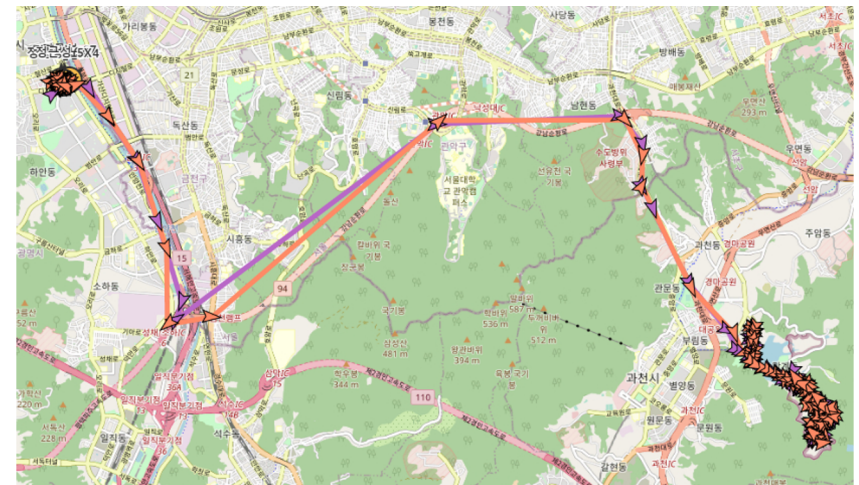
Trip Monitoring

Stop Detection

- A **stop** (or **stay**) is a single instance of an object spending some time in one place.
- When participants stays some point more than 20 minutes, our server automatically generate **stop** record.
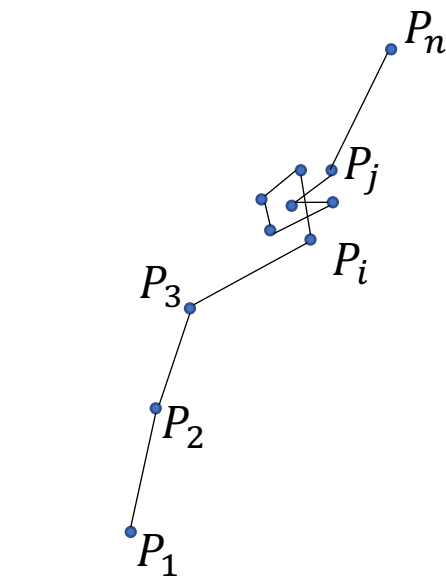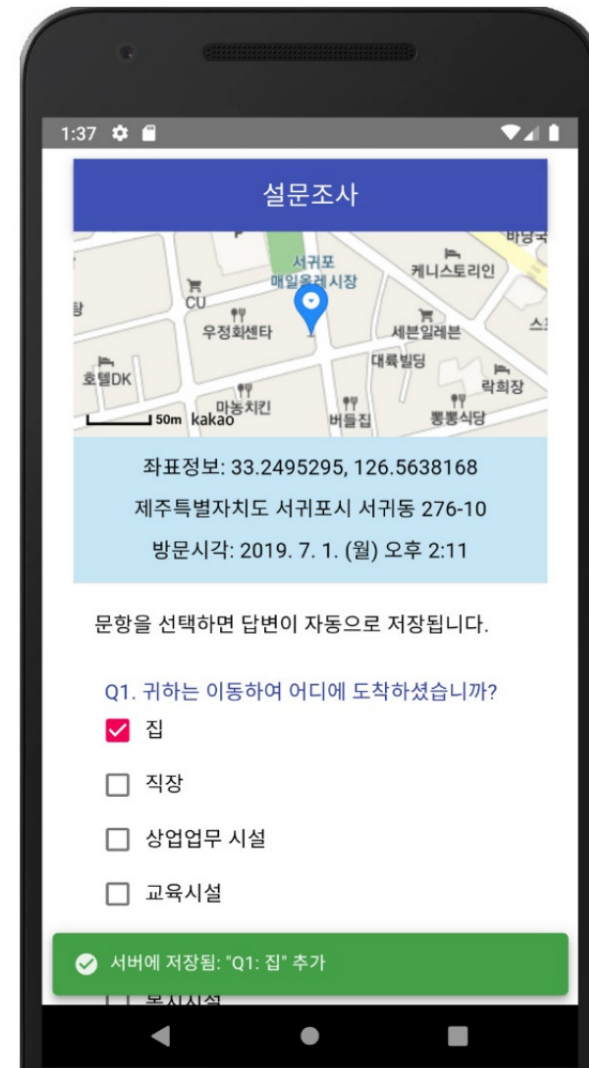
Original GPS Points
$P = \{P_1, P_2, \dots, P_n\}$
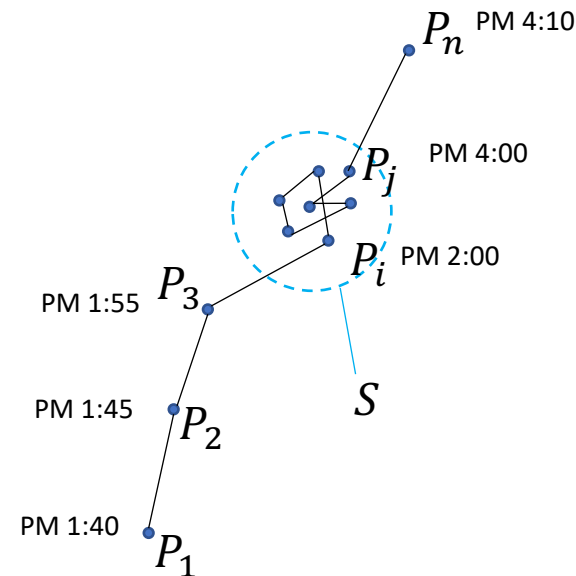
Detecting Stop $S = \{P_i, \dots, P_j\}$
All points in S placed inside given radius r and the time interval between (P_i, P_j) has elapsed given time t.
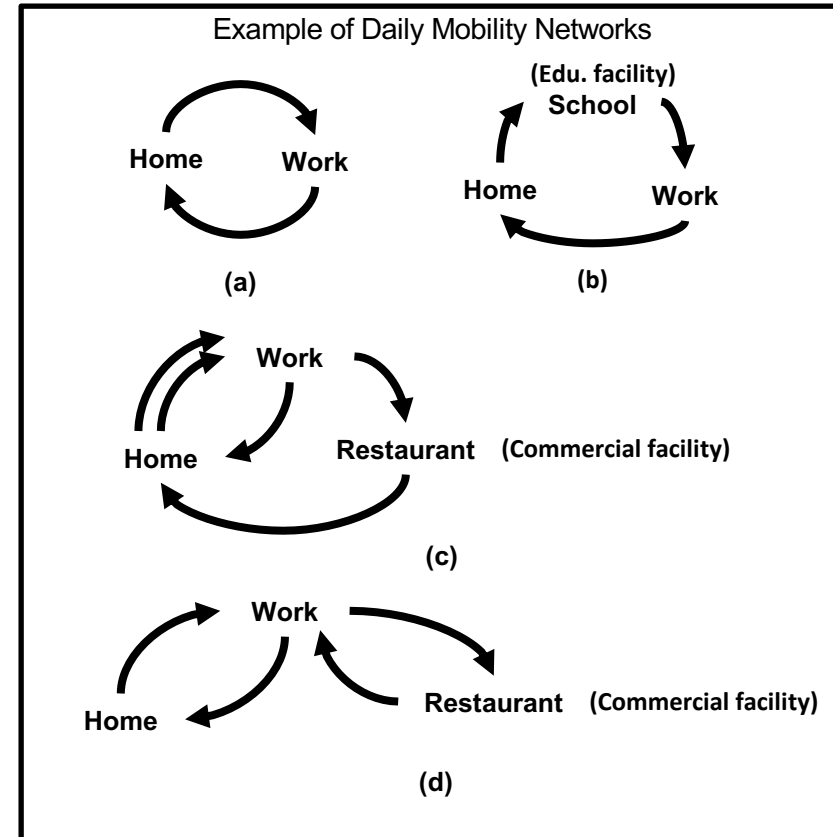
Online Survey

- Survey questions for each detected stop
  - The participants received a reminder message to complete the only survey questions at 8:00pm every evening.
  - By clicking on one of the places visited, the participants could answer the questions.

- Online Survey Questions
  - Stop categories (Special places and Activities)
    - Home, working place, or other facilities (commercial, educational, medical, welfare center, cultural, and sports).
  - Perceived mobility environment
    - Single question : "How satisfied are you with the moving environment (e.g., road conditions, etc.)
  - Transportation mode used to visit the place
    - Public bus, subway, car and so on.

Data Cleaning

- Goal
  - Many things can degrade GPS positioning accuracy. Common causes include:
    - Satellite signal blockage due to buildings, bridges, etc.
    - Indoor or underground use
  - Filtering GPS outlier on stream with time-derivatives of position (velocity, acceleration, jerk, etc.)
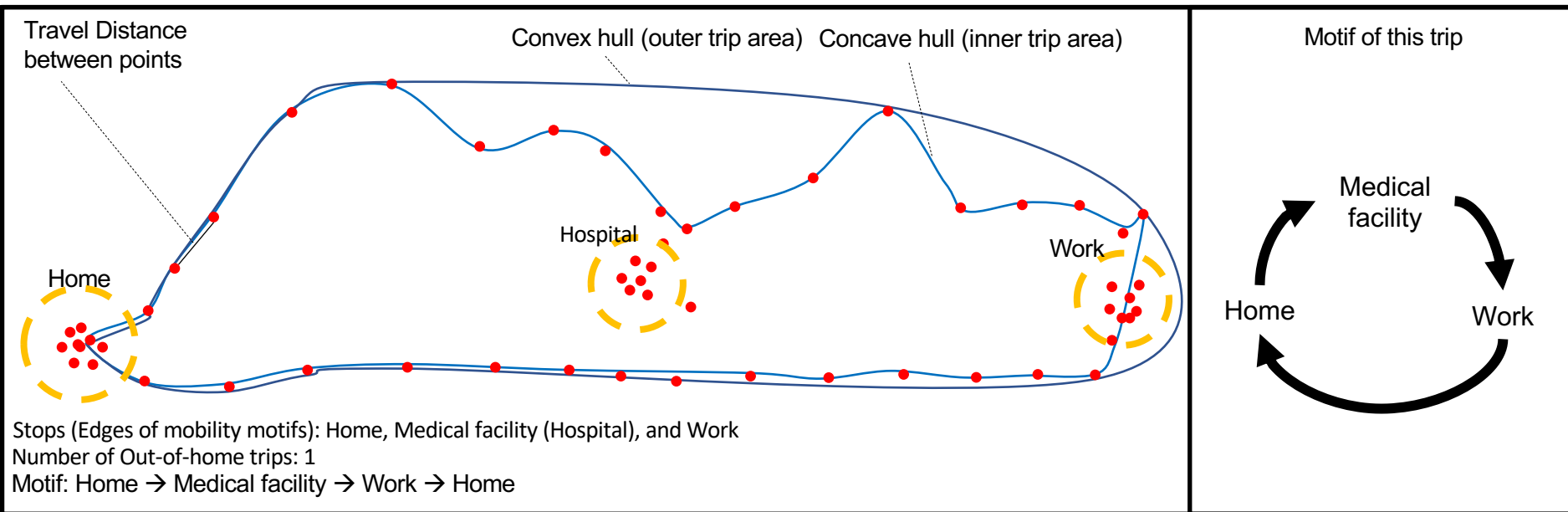

Walking Path Measured by GPS

Measures

- Travel distance (km/day)
  - Sum of distance between points

- Average number of edges/nodes from daily mobility motifs
  - Network motifs are recurrent and statistically significant subgraphs or patterns of a larger graph
  - The mobility motifs can be found by detecting mobility network of **stops.**

Example of Daily Mobility Networks

(Edu. facility)
School

Home   Work

Home   Work

(a)   (b)

Work

Home   Restaurant   (Commercial facility)

(c)

Work

Home   Restaurant   (Commercial facility)

(d)

Measures (Example)

Travel Distance between points

Convex hull (outer trip area) Concave hull (inner trip area)

Home

Hospital

Work

Stops (Edges of mobility motifs): Home, Medical facility (Hospital), and Work
Number of Out-of-home trips: 1
Motif: Home → Medical facility → Work → Home

Motif of this trip

Medical facility

Home

Work

Example: The measures in one-day-trip GPS point data

A Summary of Measures

- Mobilities
  - **Perceived mobility environment**: "How satisfied are you with the moving environment (e.g., road conditions, convenience facilities, etc.) of the route you traveled to this place?"
  - **The number of out-of-home trips**: "On average how many times do you go out in a week?"
  - **Daily travel distance**: dividing the total travel distance by the total number of days of data collection
  - Daily motif patterns
    - **Nodes**: the places visited
    - **Edges**: the travel route between nodes
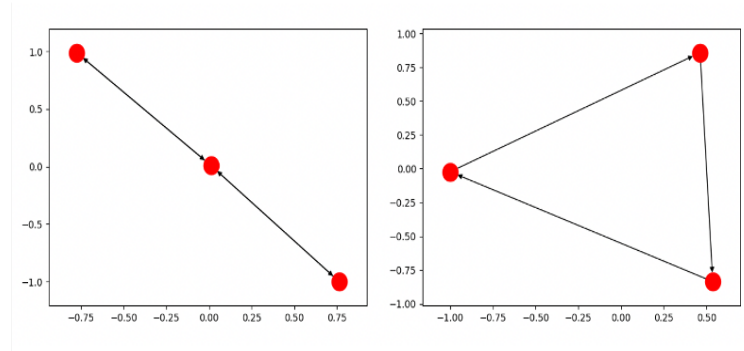

- **Life Satisfaction**
  - Participants answered the following questions using a 5-point Likert-type scale: "How satisfied are you with your life in general?"
  - Skewness = -0.18, kurstosis = -0.06.

Data sets we collected so far

year	2016	2019	2019
#	76 wheelchair users	35 people without disabilities	96 wheelchair users
Data collection methods	Offline survey GPS data from mobile phone application	GPS data from mobile phone application	Offline survey GPS data from mobile phone application Online survey from mobile phone application
Data collection period	1-3 weeks	2 weeks	1-4 weeks
Data collection interval	60 sec.	60 sec.	60 sec.
# of GPS points	273,461	192,984	1,182,527

Results and Conclusion

Exemplary Mobility Patterns of the Study Participants
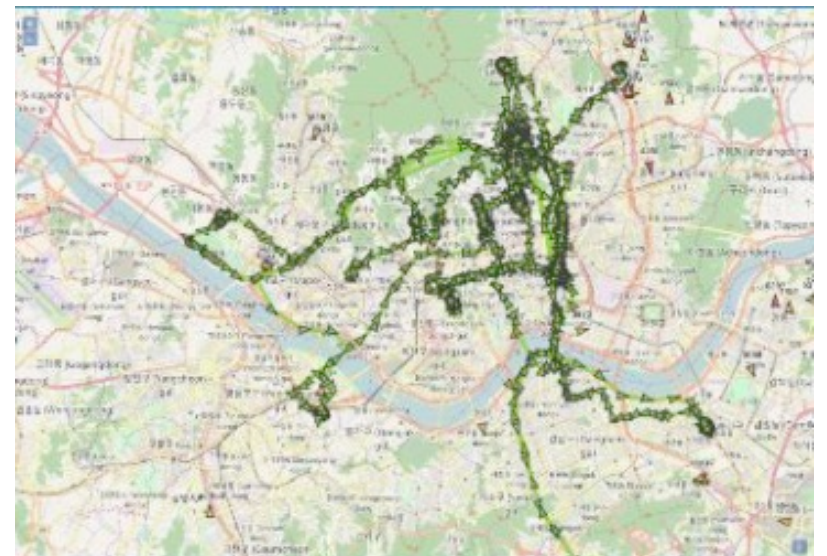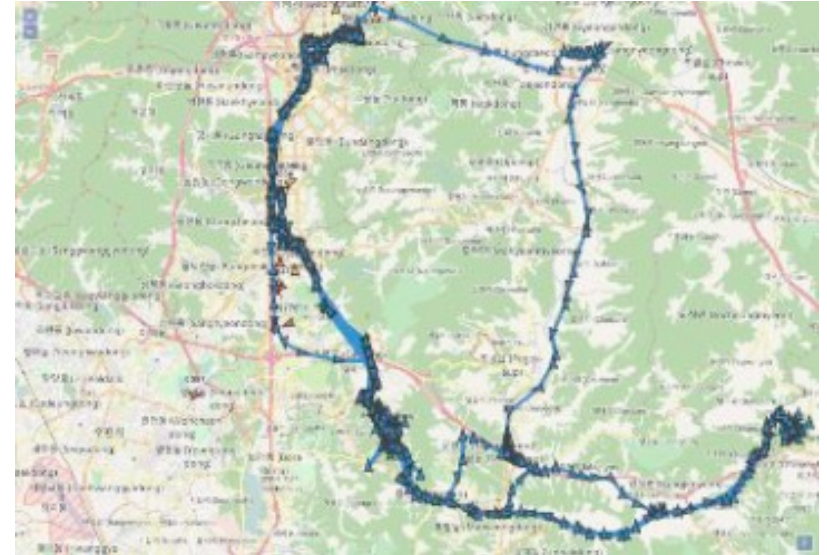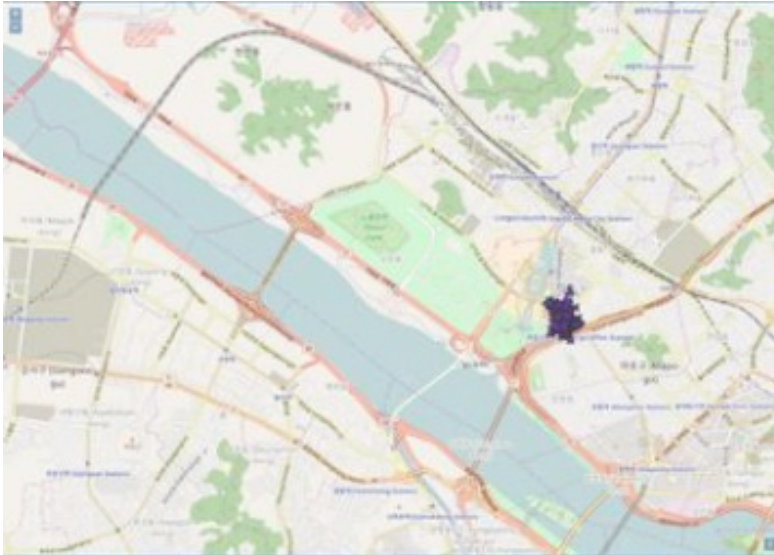
Percentages of Wheelchair Users and People without disabilities moving by time
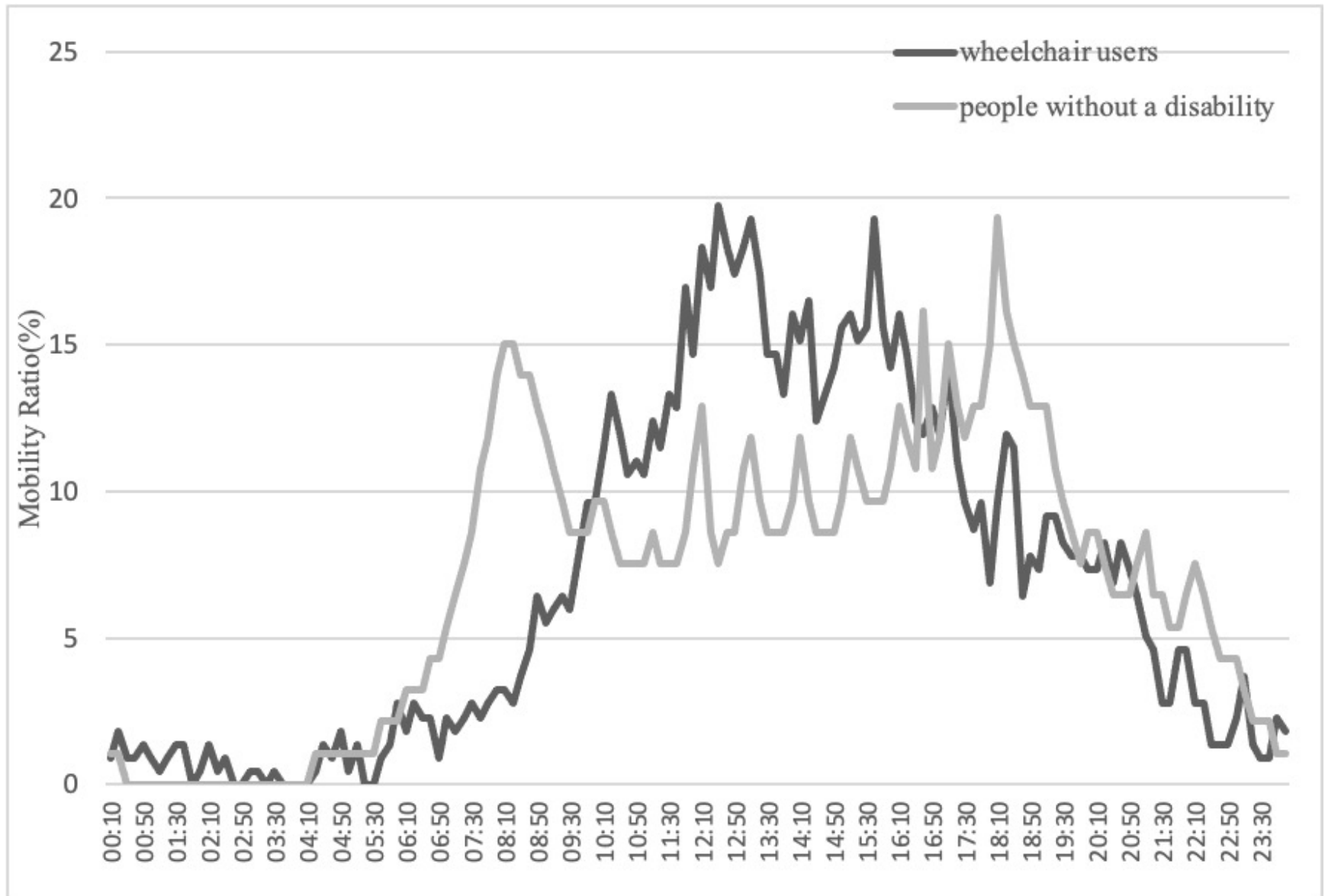
Socio-demographic Characteristics

Variables	Total Sample
Age (years)	50.83 (SD = 12.14)
Gender	
Male	57 (66.28%)
Female	29 (33.72%)
Marital Status	
Married	22 (25.88%)
Widowed	3 (3.53%)
Divorced	7 (8.24%)
Not married	51 (60.00%)
Living Together	2 (2.35%)
Education (highest level of degree)	
Less than elementary school	20 (23.81%)
Middle school	12 (14.29%)
High school	27 (32.14%)
College	21 (25.00%)
Graduate	4 (4.76%)
Life satisfaction	
Very dissatisfied	5 (5.81%)
Dissatisfied	10 (11.63%)
Neither dissatisfied or satisfied	40 (46.51%)
Satisfied	22 (25.58%)
Very satisfied	9 (10.47%)

Mobility of the Study Participants

Variables	Total Sample
Average number of out-of-home trips per week	Mean = 5.37 (SD = 1.61) Min = 2, Max = 7.5
Intention to go out I do not want to go out. I want to go out and I can go out whenever I want to. I want to go out but I cannot go out even if I want to.	 5 (5.81%) 60 (69.77%) 21 (24.42%)
Comfort level with going out Very uncomfortable Somewhat uncomfortable A little uncomfortable Not at all uncomfortable	 23 (26.74%) 48 (55.81%) 10 (11.63%) 5 (5.81%)
Daily travel distance (km/day)	36.55 (27.42)
Motif (daily) Average number of nodes Average number of edges	 2.29 (0.78) 2.12 (1.13)
Perceived mobility environment (1=very unsatisfied ~ 5=very satisfied)	2.27 (0.67)

Regression Analysis of Life Satisfaction

Variables	b	S.E.	Beta	t
Social network size	0.08	0.03	0.27	2.28[*]
Social discrimination	-0.19	0.14	-0.16	-1.40
Perceived mobility environment	0.42	0.17	0.28	2.45[*]
Number of trips (per week)	-0.07	0.08	-0.10	-0.82
Average number of edges (daily motif)	0.24	0.11	0.27	2.23[*]
Travel distance (km/day)	0.00	0.00	0.01	0.04
Disability level	0.01	0.02	0.08	0.69

Note: [†] $p < 0.10$, [*] $p < 0.05$, [**] $p < 0.01$. Multiple R-square = 0.22, Adj. R-square = 0.13, F = 2.51 (df = 7, 61), $p < 0.05$.

Conclusion

- Travel patterns of people with physical impairment are considerably diverse.

- The findings suggest that wheelchair users are more likely to be satisfied with their lives when they can visit more places as they desire and when they find those places to be easily accessible.

- Neither traveling further nor going out more frequently was significantly associated with life satisfaction in this study sample.

The Working Projects

- Research questions:
  - How is mobility associated with depressive symptoms of wheelchair users?
  - How can we categorize mobility patterns of the disabled based on their social participation and social service usages? Can we identify people's social participations/activities based on GPS data?

- Expanding data sources:
  - Mobility data based on Call Detail Records (from telecommunication operators)

- The development of analytic platform/engine: