TECHNISCHE UNIVERSITÄT WIEN
Vienna University of Technology

# *"EXTRACTION OF USER'S STAYS FROM GPS LOGS: A COMPARISON OF THREE SPATIO-TEMPORAL CLUSTERING APPROACHES"*

International Master in Cartography

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**Wien 16.12.2015**

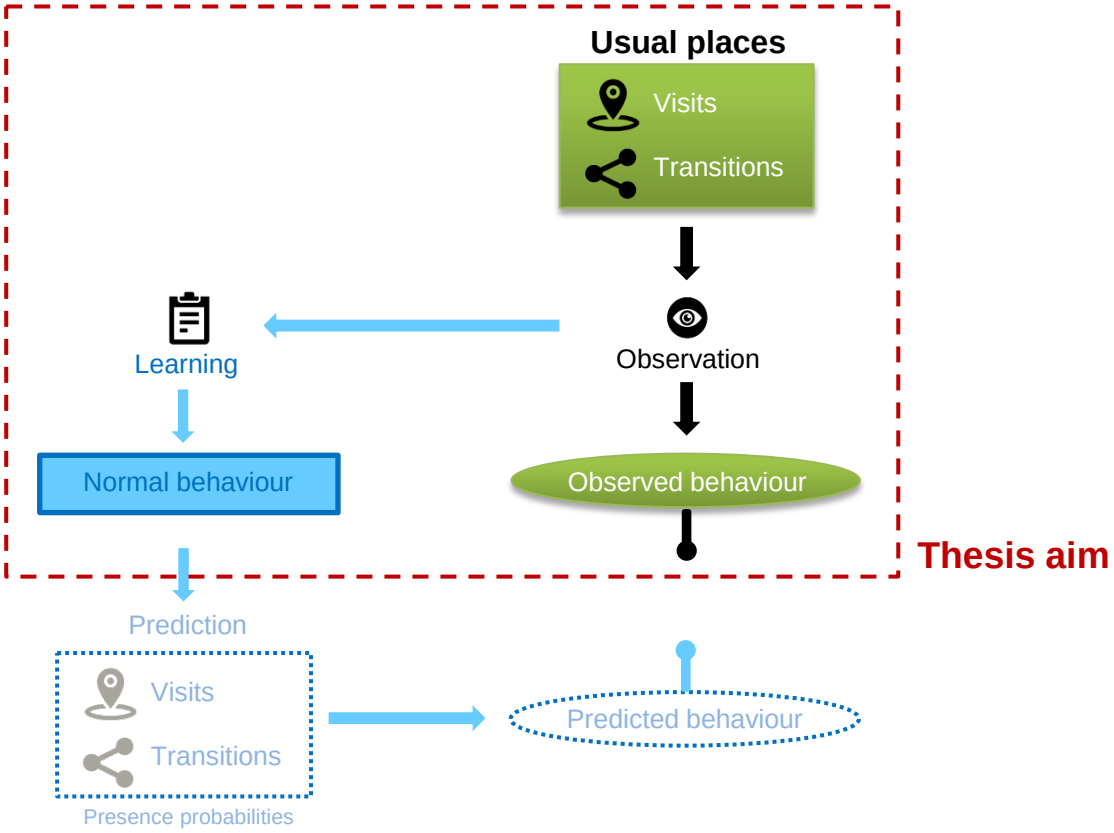
# Overview

*“EXTRACTION OF USER’S STAYS FROM GPS LOGS:*
*A COMPARISON OF THREE SPATIO-TEMPORAL CLUSTERING APPROACHES”*

- 1. Introduction
- 2. Theory
- 3. Method
- 4. Implementation
- 5. Results
- 6. Conclusions

# 1. Introduction

**USE CASE**




ICONS from www.flaticon.com

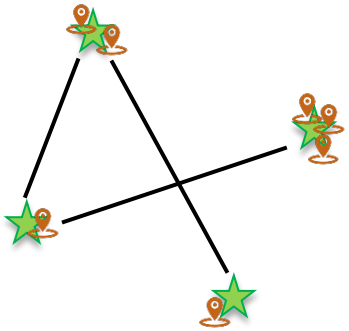
# 1. Introduction

## Research identification

### Research objectives

(i) Detecting **visited places** in user's life in an automated way

(ii) Characterising **stays** at visited places and **transitions** between them



**Visited place**

Geographic **location** in which a **user** has been located during a **minimum period of time** (stay).

**Stay**

Physical **presence** of a **user** at a geographic location during a period of **time**.

**Transition**

**Change** of presence between **two different** geographic **locations** in which user has a **stay**.

→ **Spatio-temporal clustering**

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# 1. Introduction

## Research identification

### Research questions

- Which spatio-temporal **clustering approach** is the most adequate?
  - **Best algorithm** to detect user's visited places?
  - **Differences** between tested algorithms?
  - Best values for algorithms **parameters?**

- Which **approach** is adequate to **characterise** stays and transitions?
  - Relevant information for **stays** representation?
  - Relevant information for **transitions** representation?

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# 2. Theory

## Clustering algorithms

- **1. Incremental clustering**

  TBC *(Kang et al. 2005)*

- **2. Incremental + density-based clustering**

  TBC *(Ye et al. 2009)* + DBSCAN *(Ester et al. 1996)*

- **3. Density-based clustering**

  DBSCAN *(Ester et al. 1996)*

## Quality Evaluation

(*Salzburg Research 2015)*

- **4 quality measures**
- **Confusion matrix**

# 2. Theory

## Clustering algorithms

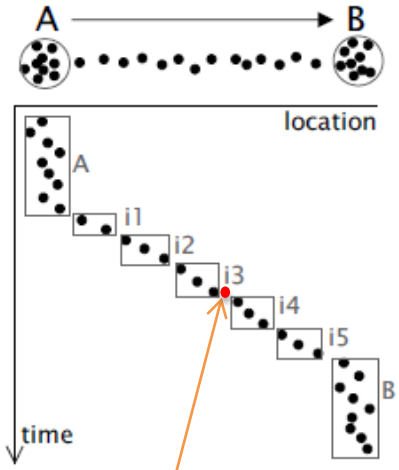
➢ **1. Incremental clustering** *(Kang et al. 2005)*

➢ Clusters **computed incrementally** as new location estimates are generated.

➢ 2 main parameters: **d** and **t** determine **number** and **size** of extracted places.

- A stream of coordinates is clustered along time
- If stream moves away from current cluster and **distance > d** ⟶ **new cluster**

- Smaller clusters, where little time spent, dropped (i1, ... , i5)
- If cluster duration: **time >= t** ⟶ **detected place** (A, B)




TBC (Kang et al. 2005)

➢ Third parameter "**L**" to determine if the user is really **moving away** from current cluster position

*If **plocs** grows beyond **L seconds** the user is really moving away and starts a new cluster*

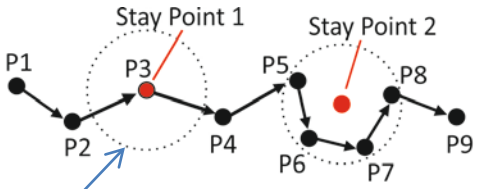
# 2. Theory

## Clustering algorithms

➢ **2. Incremental + density-based clustering** *(Ye et al. 2009)*

*1st Algorithm (Ye et al. 2009)* + *2nd DBSCAN (Ester et al. 1996)*

**Stay point**: *a geographic region in which the user stays for a while*




Two types considered:

➢ Individual maintains **stationary** at a point for over a time threshold (**> t**)

*(e.g. enters a building)*

➢ Individual **wanders around** within a spatial region (**<= d**) for over a time threshold (**> t**)

*(e.g. park, square)*

- Mean longitude and latitude of GPS points construct a stay point
- *Arrival time* and *leaving time* respectively equals timestamp of **first** and **last** GPS point constructing stay point. *(P5, P8)*

# 2. Theory

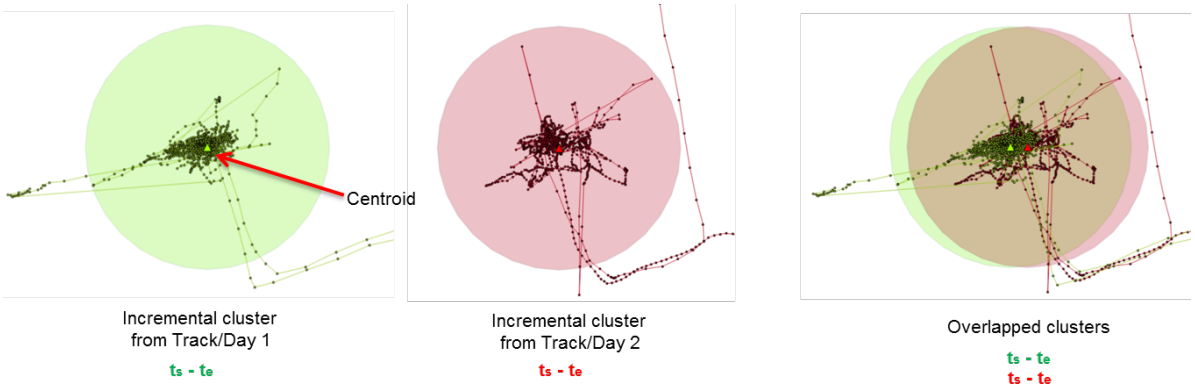
## Clustering algorithms

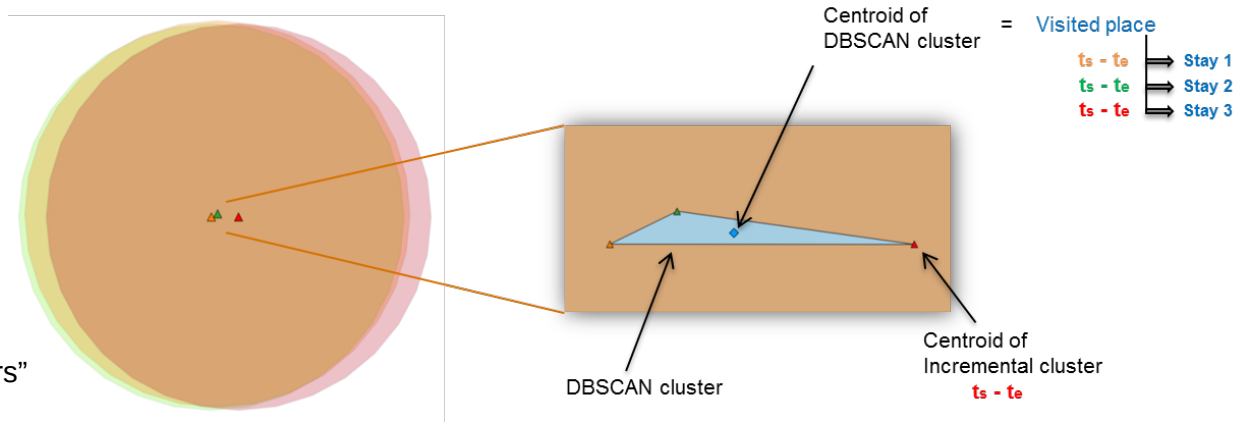
➢ **2. Incremental + density-based clustering** *(Ye et al. 2009)*

*1st Algorithm (Ye et al. 2009)* + *2nd DBSCAN (Ester et al. 1996)*

*Fuzziness of locations*

Authors perform a second clustering of the initial **stay points** detected → ***DBSCAN***




Final visited place will be the "cluster of the incremental clusters"

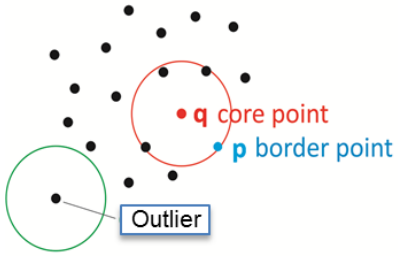
# 2. Theory

## Clustering algorithms

➢ **3. Density-based clustering** *DBSCAN (Ester et al. 1996)*

➢ **For each point of a cluster**, the cardinality of the neighbourhood of a given radius (***Eps***) has to exceed a threshold (***MinPts***).

*i.e. Within an Eps radius, a minimum number of points should be present*

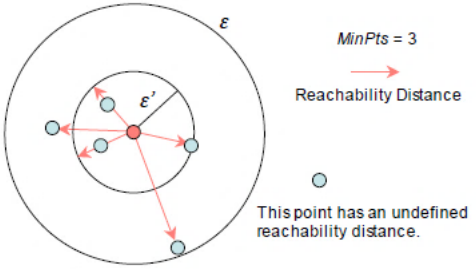



DBSCAN

To determine optimum ***Eps*** and ***MinPts*** → auxiliar algorithm

Generalizes DBSCAN creating an ordering of the points

- Allows extraction of clusters with **arbitrary values for ε** (*Eps*)
- A „maximum Eps“ (ε) to consider is selected as input
- Calculates **reachability-distance** of every point in dataset




OPTICS cluster (Ankerst et al. 1999)

*(Ankerst et al. 1999)*

➢ Does not generate a unique clustering, but

➢ Helps **choosing optimal *Eps***

OPTICS

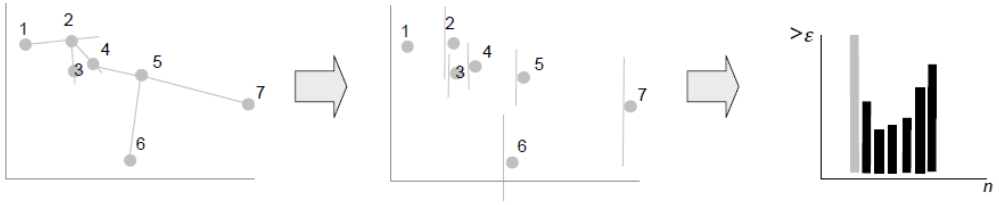
# 2. Theory

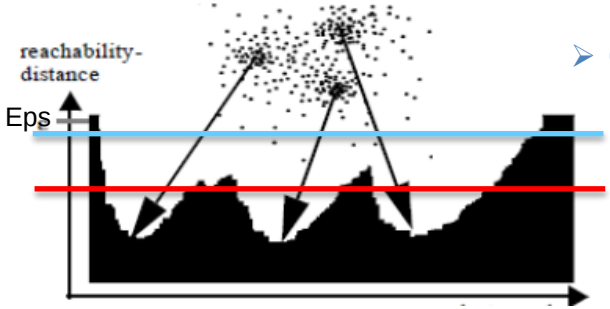
## Clustering algorithms

➢ **3. Density-based clustering** *DBSCAN (Ester et al. 1996)*

***Reachability plot***

- *Bar chart that shows each point's reachability distance in the order the object was processed*
- Clearly show cluster structure of the data




Reachability Plot (Ankerst et al. 1999)

➢ **Choosing optimal *Eps***

Eps 6 → 1 cluster

Eps 4 → 3 clusters

*(Ankerst et al. 1999)*

OPTICS

# 2. Theory

## Quality Evaluation *(Salzburg Research 2015)*

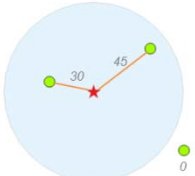
Detected place = **Clusters** generated by algorithm

Tagged places = **Real locations** visited by user (GTD)

### ➢ Quality measures

**SPATIAL**

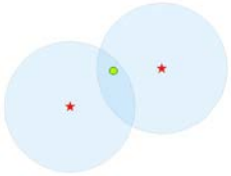
**1. Spatial accuracy (Qsa)**





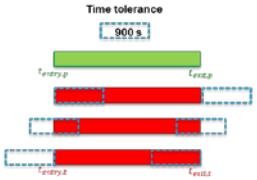
*Circular buffer around tagged places*

**2. Spatial uniqueness (Qsu)**



**TEMPORAL**

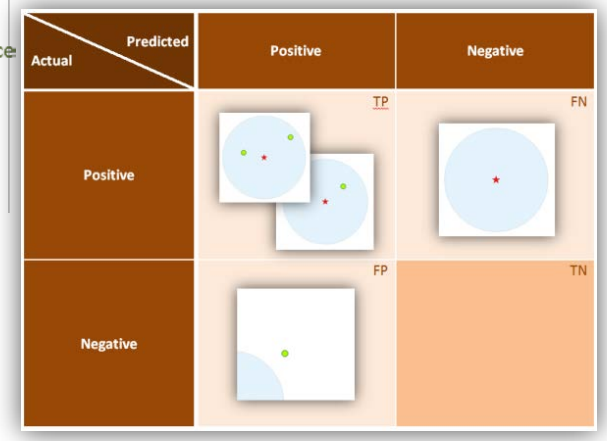
**3. Temporal accuracy (Qta)**




**4. Amount of temporal incorrectness (Qti)**

$$Q_{ti} := 1 - \frac{N_{incorr}}{D} = \frac{N_{corr}}{D}$$

### ➢ Confusion matrix




**CLASSES**

1. **True positive (TP).** A tagged (real) place is detected.
2. **False negative (FN).** A tagged (real) place is not det.
3. **False positive (FP).** A detection is obtained where there is no tagged (real) place.

$$Precision = \frac{TP}{TP + FP}$$ → Exactness of the model

$$Recall = \frac{TP}{TP + FN}$$ → Completeness of the model

$$F\ measure = \frac{2 * (Precision * Recall)}{Precision + Recall}$$ → **Effectiveness** of retrieval

# 3. Method

**Dataset**

**Ground truth data (GTD).** GPS logs:

- Collected by **4** researchers
- **40 days** campaign
- **3 sec** sampling rate
- *Wegeprotokoll* with **stays** and **transitions**
- Real locations = ***Tagged Places***

**Spatio-temporal clustering**

Dataset

Data pre-processing

**TASKS**

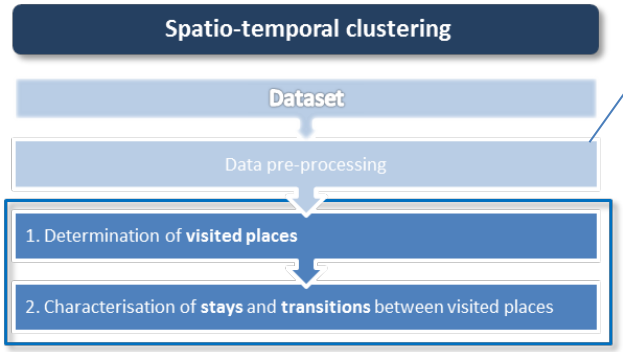
1. Determination of **visited places**

2. Characterisation of **stays** and **transitions** between visited places

**Thesis innovation**

- Incremental clustering
- Incremental + Density-based clustering
- Density-based clustering

# 3. Method




## Data pre-processing

Dealing with **systematic** and **random** positioning errors

**Filtering**
- **Removal** of points with **equal timestamp**
- **Removal** of points with **equal geometry**
- Correction of **tunnels**
- Removal of **spikes**

**Smoothing**
- **Kernel** based approach

## 1. Determination of visited places

**1.1. Incremental clustering**
*(Kang et al. 2005)*

**1.2. Incremental + Density-based clustering**
*(Ye et al. 2009)* **+** *DBSCAN (Ester et al. 1996)*

**1.3. Density-based clustering**
*DBSCAN (Ester et al. 1996)*

**1.4. Quality Evaluation**
Implementation *(Salzburg Research 2015)*

## 2. Characterization of stays and transitions

**2.1. Extraction of stays at visited places**
- Process for stays extraction

**2.2. Extraction of transitions between visited places**
- Process for transitions extraction

**2.3. Quality Evaluation of the extraction**
- Confusion matrix
- Comparison of different parameter settings

**2.4. Characterization of stays and transitions**
- User profile and visualizations

# 3. Method

## 1. Determination of visited places

### GOALS

- Determining **visited places** in a user's daily life
- **Evaluation** of clustering **algorithms**

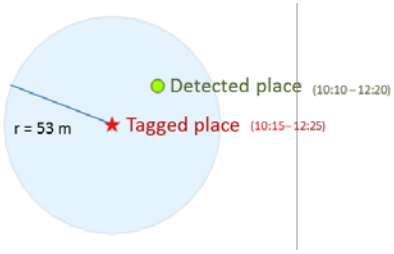
### RESULTS

- **Clusters** representing visited places
- **Comparison** of clustering algorithms **performance**
- **Assessment** of the algorithms and selection of the **best**

### TARGETS

**Quality** of the clustering

- **SPATIAL**
  - **Precision** > 66%
  - **Recall** > 66%
- **TEMPORAL**
  - **Times detected** > 66%



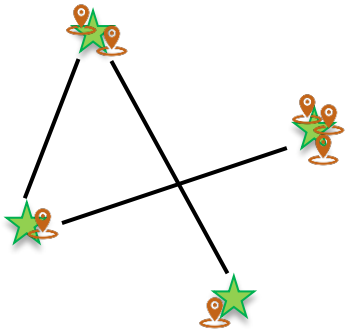

ICONS from www.flaticon.com

# 3. Method

## 2. Characterization of stays and transitions

### GOALS

- Representing **stays** at places with characteristic values
- Representing **transitions** with characteristic values
- Evaluating **time extraction** performed by spatially best algorithm



### RESULTS

- User's dwell time at significant locations (**stays**)
- Transitions between significant locations (**transitions**)
- **Evaluation** of the stays and transitions **extraction**

### TARGETS

**Quality** of the extraction

- **STAYS** detection
  - **Precision** > 66%
  - **Recall** > 66%
- **TRANSITIONS** detection
  - **Precision** > 66%
  - **Recall** > 66%

ICONS from www.flaticon.com

# 4. Implementation

## 1.1. Incremental clustering *(Kang et al. 2005)*

➢ **Parameters**

- **Reference values**

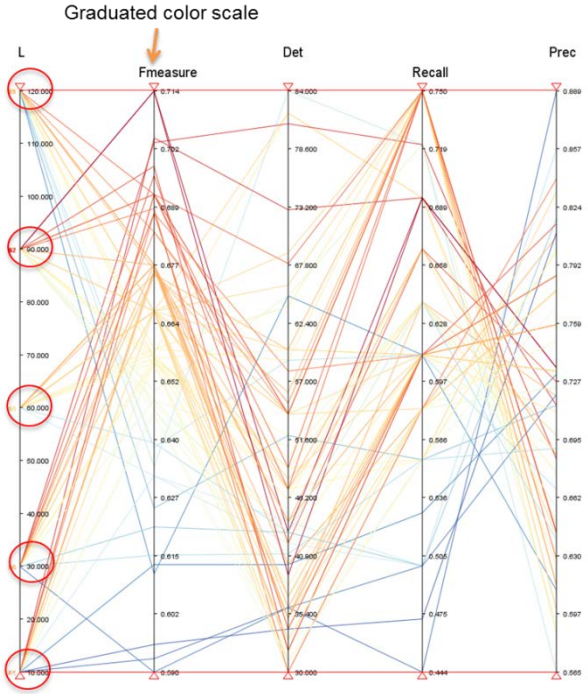
  **d =** (30 / 50 m)
  **t =** (300 / 1800 sec)
  **L =** (no reference value)

Tested values:

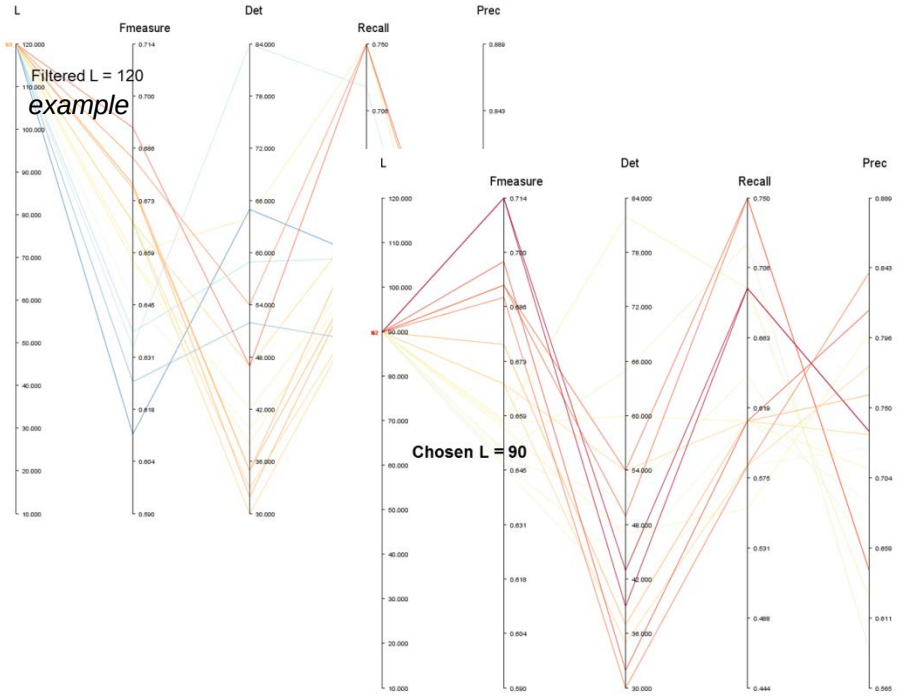
| d (m) | t (s) | L (s) |
|---|---|---|
| 20 | 600 | **10** |
| 30 | 900 | **30** |
| 40 | 1200 | **60** |
| 50 | 1500 | **90** |
| | | **120** |

4 x 4 x 5

**80** combinations




Parallel coordinates plot




Maximum **F measure** results determined **optimum** value **for L**

# 4. Implementation

## 1.1. Incremental clustering *(Kang et al. 2005)*

### ➢ Parameters

- **Tested values**

**L =** 90 sec

| d (m) | t (s) |
|---|---|
| 20 | 300 |
| 26.5 | 600 |
| 30 | 900 |
| 40 | 1200 |
| 53 | 1500 |
| 60 | 1800 |
| 70 | 2100 |
| 80 | |
| 90 | |
| 100 | |
| 200 | |

11 x 7

**77** combinations

➢ Implemented additional Java class for **batch processing**

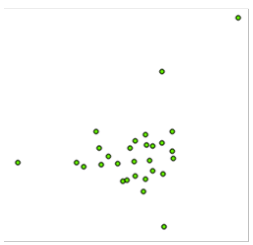
# 4. Implementation

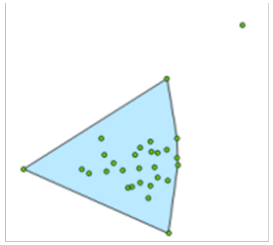
## 1.2. Incremental clustering + density-based clustering

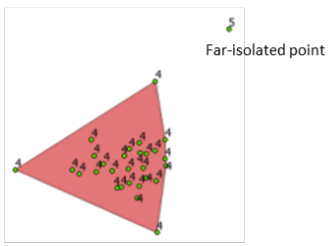
*1st Algorithm (Ye et al. 2009)* ~~*+ 2nd DBSCAN (Ester et al. 1996)*~~

*+ 2nd ConvexHull*

- **Alternative** to DBSCAN
- Seamless integration within our process
- Almost same performance than DBSCAN
- **Own** solution

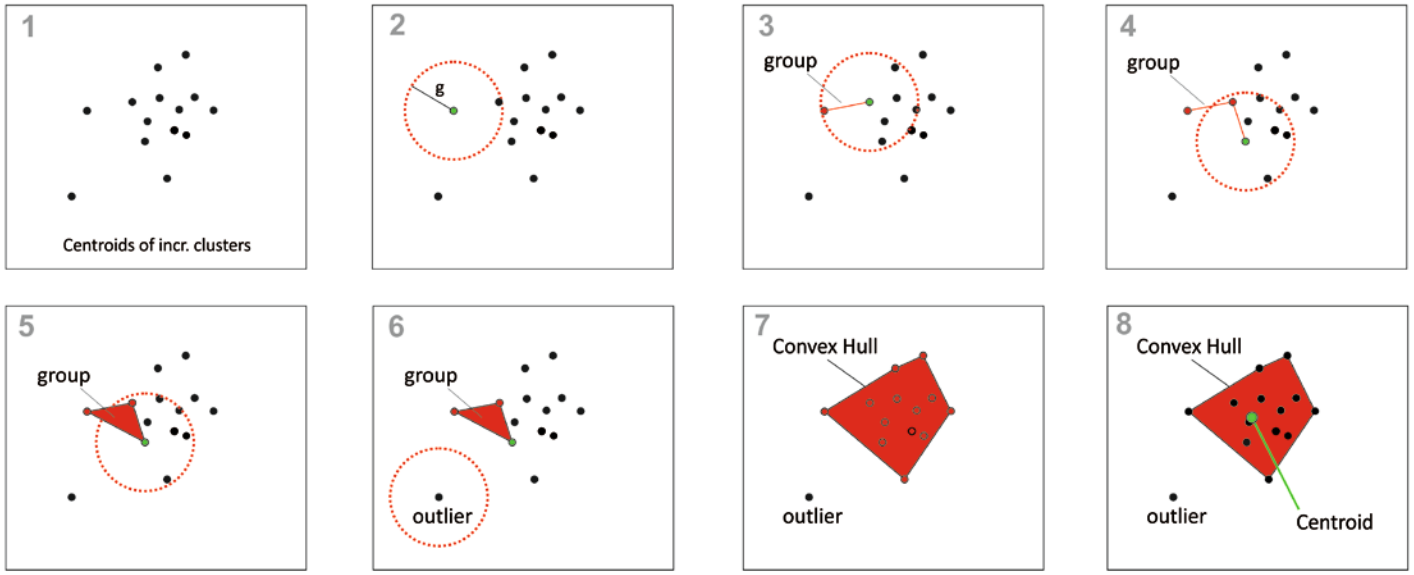

Incremental clusters


DBSCAN cluster



Convex hull around grouped points

*Grouping of points → Creation of convex hull → Centroid calculation*



# 4. Implementation

## 1.2. Incremental clustering + density-based clustering

*1st Algorithm (Ye et al. 2009)* ~~*+ 2nd DBSCAN (Ester et al. 1996)*~~
*+ 2nd ConvexHull*

➢ **Parameters**

- **Reference values**

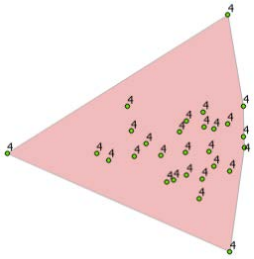
  **d =** (200 meters)
  **t =** (1800 seconds)

  **g =** (40 meters) ← *ConvexHull* ← *DBSCAN* ← *OPTICS*

- **Tested values**

| d (m) | t (s) |
|---|---|
| 26.5 | 300 |
| 53 | 600 |
| 100 | 900 |
| 200 | 1200 |
| 300 | 1800 |
| 400 | 2400 |
| 500 | 3000 |
| 600 | |
| 700 | |

g (m)
40



9 x 7 **63** combinations

➢ Implemented additional Java class for **batch processing**

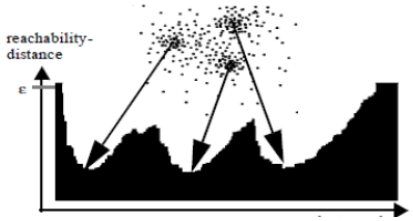
# 4. Implementation

## 1.3. Density-based clustering *DBSCAN (Ester et al. 1996)*

To determine optimal parameters: ***Eps*** and ***MinPts*** → *OPTICS (Ankerst et al. 1999)*

ELKI
Environment for DeveLoping KDD-Applications Supported by Index-Structures

*Java software used for OPTICS/DBSCAN clustering*



Reachability Plot (Ankerst et al. 1999)

Reachability plot for 450.000 points → **not operative**

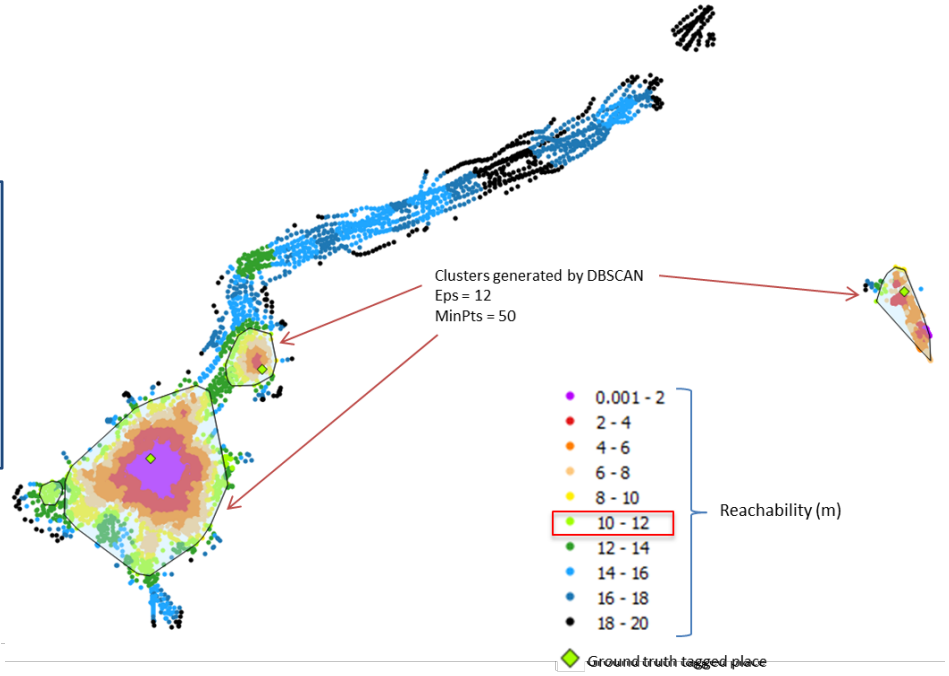
Alternative **visual approach** with QGIS

ELKI output

**QGIS**

- Represented **points** with their **reachability** values
- Represented **ground truth places**
  - ➢ Chosen reachability determines clusters to be obtained
  - ➢ Visual check of the whole dataset

**DBSCAN clustering** with determined ***Eps***



# 4. Implementation

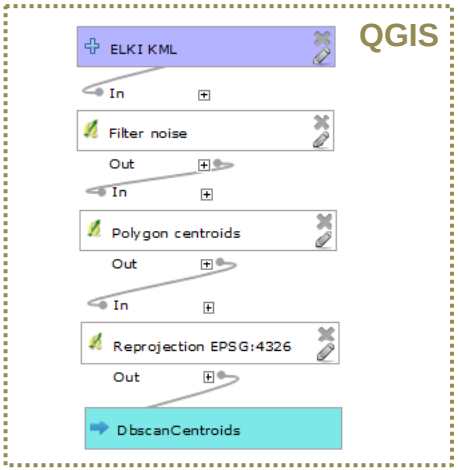
## 1.3. Density-based clustering *DBSCAN (Ester et al. 1996)*

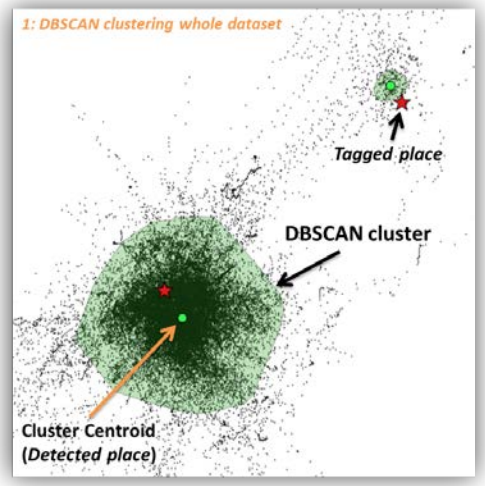
- **Tested values**

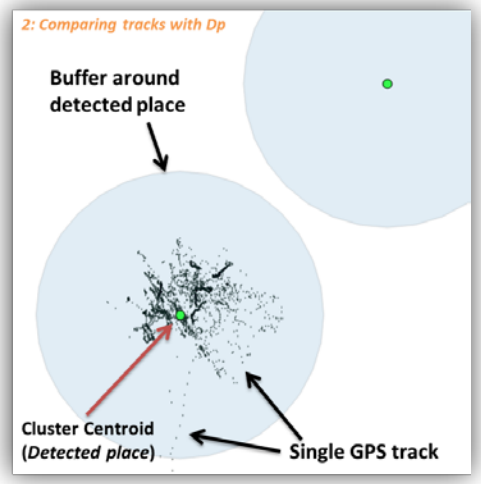
| MinPts | Eps (m) |
|---|---|
| 20 | 2 |
| 30 | 3 |
| 40 | 6 |
| 50 | 9 |
| 60 | 12 |
| 70 | 15 |
| 80 | 18 |
| 90 | |
| 100 | |
| 110 | |
| 120 | |

ELKI

11 x 7 **77** combinations

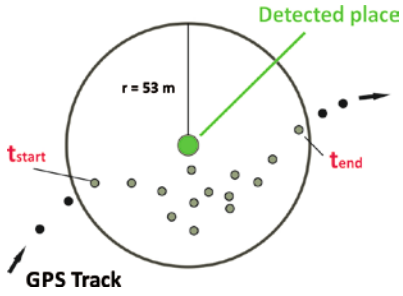



**Java**

Implemented class for dwell **time extraction** and **batch processing**



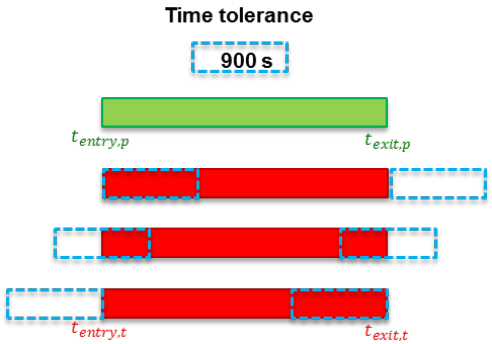
# 4. Implementation

## 1.4. Quality Evaluation

- **Developed** at Salzburg Research → Mostly **implemented** within this thesis (Java)
- Applied on **3 spatio-temporal** clustering approaches
- **Spatial** and **temporal** component of detecting the GTD tagged places
- **Measures** to evaluate spatial and temporal accuracy of the estimations
- Performance compared in a **confusion matrix**

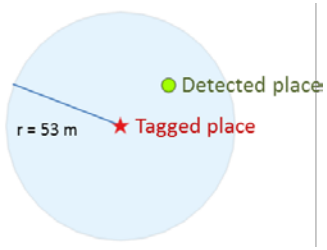
Detected place = **Clusters** generated by algorithm
Tagged places = **Real locations** visited by user (GTD)

➢ Detected places **related** to tagged places for each test user




***TEMPORAL RELATION***

***SPATIAL RELATION***

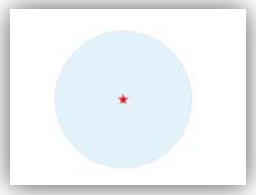


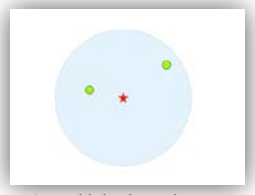

*Circular buffer around tagged places*

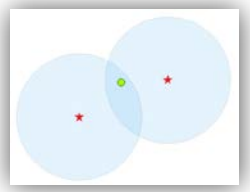
Mean time deviation calculated for each tP

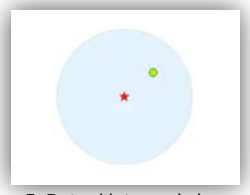
$$\Delta t_{t,p} = \frac{\left|(t_{entry,p} - t_{entry,t})\right| + \left|(t_{exit,p} - t_{exit,t})\right|}{2}$$


1. Det. without tagged place


2. Tagged place without det.

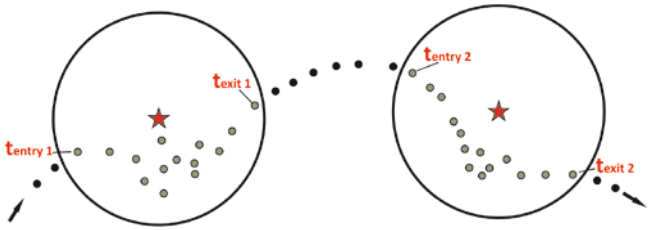

3. Multiple detections


4. Mult. tagged places


5. Det. with tagged place

# 4. Implementation

## 2.1. Extraction of stays // 2.2. Extraction of transitions



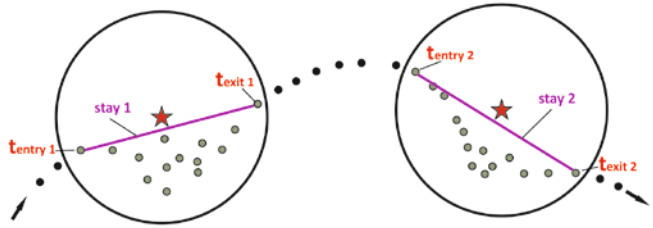

```
// Cluster duration
long currentClusterDuration = calculateDurationOfList(currentCluster);

if (currentClusterDuration >= timeParam) {
    boolean withInDistance = false;
    int lastInCluster = 0;
    lastInCluster = currentCluster.size() - 1;

    Date timeEntry = currentCluster.get(0).getTimestamp();
    Date timeExit = currentCluster.get(lastInCluster).getTimestamp();
    TimeElement timeElement = new TimeElement(currentClusterCentroid, timeEntry, timeExit);
    Transition transition = null;

    for (DetectedPlace dP : detectedPlaces) {
        // Calculate distance between currentCluster and each already detected DetectedPlac
        double clusterToDpDistance = calculateDistance(dP.getLocation().getCoordinate(), cu
```

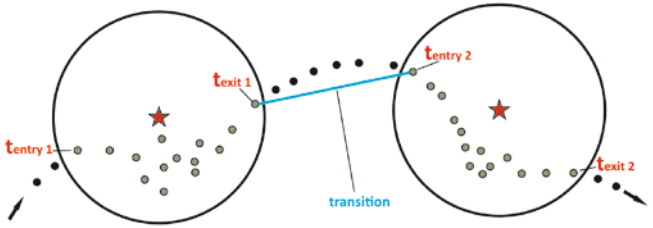
### STAYS




- Stored in each detected place
- Duration = texit - tentry

| DpID | VisitID | TimeStart | TimeEnd | Duration(s) | Month | Day | WD |
|---|---|---|---|---|---|---|---|
| 1 | 0 | 12/08/2014 16:27 | 12/08/2014 17:48 | 4904 | 8 | 12 | Tue |
| 1 | 1 | 13/08/2014 16:28 | 13/08/2014 17:10 | 2488 | 8 | 13 | Wed |
| 1 | 2 | 13/08/2014 17:45 | 13/08/2014 23:59 | 22450 | 8 | 13 | Wed |
| 1 | 2 | 14/08/2014 00:00 | 14/08/2014 08:16 | 29814 | 8 | 14 | Thu |
| 1 | 3 | 14/08/2014 16:14 | 14/08/2014 16:32 | 1061 | 8 | 14 | Thu |
| 1 | 4 | 17/08/2014 18:32 | 17/08/2014 23:59 | 19659 | 8 | 17 | Sun |
| 1 | 4 | 18/08/2014 00:00 | 18/08/2014 08:04 | 29042 | 8 | 18 | Mon |
| 1 | 5 | 18/08/2014 16:18 | 18/08/2014 16:53 | 2104 | 8 | 18 | Mon |
| 1 | 6 | 18/08/2014 17:41 | 18/08/2014 18:28 | 2819 | 8 | 18 | Mon |
| 1 | 7 | 19/08/2014 16:01 | 19/08/2014 16:37 | 2165 | 8 | 19 | Tue |
| 1 | 8 | 19/08/2014 18:09 | 19/08/2014 18:46 | 2231 | 8 | 19 | Tue |

### TRANSITIONS




- Stored with associated data
- Duration = tentry 2 – texit 1

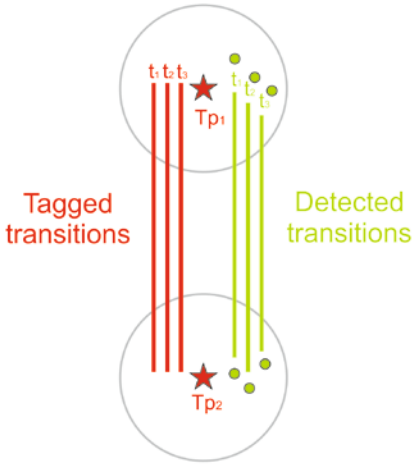
| TrID | Orig. | Dest. | TimeDeparture | TimeArrival | Distance(m) | Duration(s) | Sp(km/h) | Mon | Day | WD | SameDay |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 2 | 12/08/2014 17:48 | 12/08/2014 17:55 | 441.0 | 405 | 3.920 | 8 | 12 | Tue | TRUE |
| 2 | 2 | 3 | 12/08/2014 20:12 | 13/08/2014 08:17 | 490.8 | 43477 | 0.041 | 8 | 12 | Tue | FALSE |
| 3 | 3 | 1 | 13/08/2014 16:01 | 13/08/2014 16:28 | 320.4 | 1623 | 0.711 | 8 | 13 | Wed | TRUE |
| 4 | 1 | 1 | 13/08/2014 17:10 | 13/08/2014 17:45 | 0.0 | 2131 | 0.000 | 8 | 13 | Wed | TRUE |
| 5 | 1 | 3 | 14/08/2014 08:16 | 14/08/2014 08:23 | 320.4 | 423 | 2.726 | 8 | 14 | Thu | TRUE |
| 6 | 3 | 1 | 14/08/2014 16:10 | 14/08/2014 16:14 | 320.4 | 264 | 4.368 | 8 | 14 | Thu | TRUE |
| 7 | 1 | 4 | 14/08/2014 16:32 | 14/08/2014 18:47 | 45377.3 | 8107 | 20.150 | 8 | 14 | Thu | TRUE |
| 8 | 4 | 5 | 14/08/2014 19:28 | 14/08/2014 19:29 | 113.6 | 96 | 4.260 | 8 | 14 | Thu | TRUE |
| 9 | 5 | 6 | 15/08/2014 09:59 | 15/08/2014 10:03 | 860.0 | 192 | 16.125 | 8 | 15 | Fri | TRUE |
| 10 | 6 | 5 | 15/08/2014 11:59 | 15/08/2014 12:02 | 860.0 | 195 | 15.877 | 8 | 15 | Fri | TRUE |

# 4. Implementation

## 2.3. Quality Evaluation of stays and transitions extraction

$$\bar{t}_{t,d} = \frac{\left|(t_{entry,d} - t_{entry,t})\right| + \left|(t_{exit,d} - t_{exit,t})\right|}{2}$$

$$if\ \bar{t}_{t,d} \leq 900\ sec\ \rightarrow Matches$$


➢ **Proportion of time extracted**

$$St_{ext} := \frac{St_d}{St_t}$$

Total time in stays detected
Total time in stays tagged (GTD)

$$Tt_{ext} := \frac{Tt_d}{Tt_t}$$

Total time in transitions detected
Total time in transitions tagged (GTD)

➢ **Confusion matrix classes**

- **True positive (TP)** — A **tagged** stay/transition is **detected**
- **False negative (FN)** — A **tagged** stay/transition is **not detected**
- **False positive (FP)** — A stay/transition is **obtained** when there is **no tagged** stay/transition

# 4. Implementation

## 2.4. Characterization of stays and transitions

➢ **Selection of best clustering algorithm**

- Selection according to maximum F measure
- Selection of best parameters settings for the best algorithm

➢ **Data mining of algorithm outputs**

- Creation of SQLite database
- Design of SQL statements
- Tests with 3 algorithms
- Processing of data for 3D visualizations

➢ **INDICATORS**

- **Stays**

**1. Number of stays at each tagged place per weekday**

1.1. Number of detected occurrences
1.2. Number of GTD occurrences (tagged)
1.3. Proportion of GTD stays detected

**2. Duration of the stays at each tagged place per weekday**

2.1. Duration of detected stays
2.2. Duration of GTD stays
2.3. Proportion of GTD stays duration detected

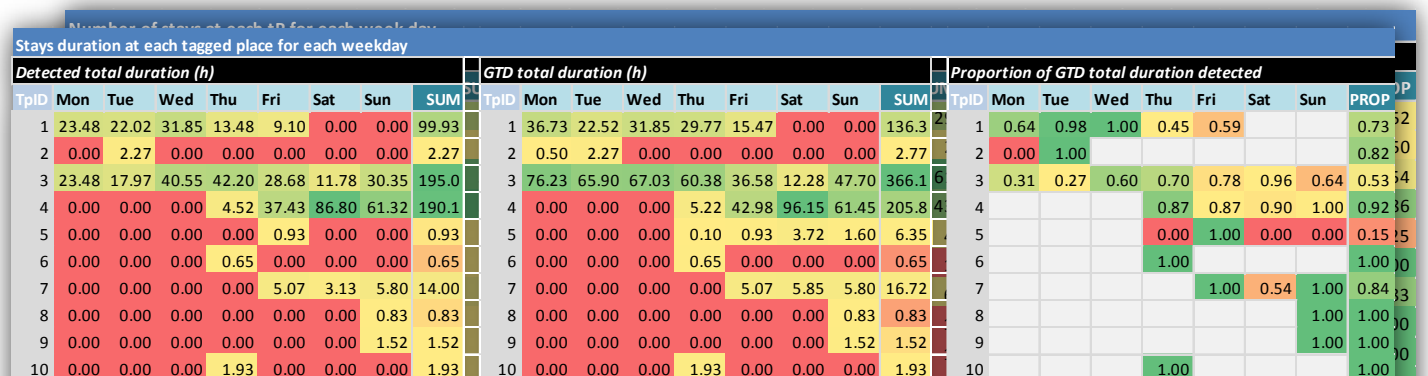
- **Transitions**

**1. Number of transitions between tagged places per weekday**

1.1. Number of detected occurrences
1.2. Number of GTD occurrences (tagged)
1.3. Proportion of GTD transitions detected

**2. Duration of the transitions between tagged places per weekday**

2.1. Duration of detected transitions
2.2. Duration of GTD transitions
2.3. Proportion of GTD transitions duration detected



Stays duration at each tagged place for each weekday

*Detected total duration (h)*

| TpID | Mon | Tue | Wed | Thu | Fri | Sat | Sun | SUM |
|---|---|---|---|---|---|---|---|---|
| 1 | 23.48 | 22.02 | 31.85 | 13.48 | 9.10 | 0.00 | 0.00 | 99.93 |
| 2 | 0.00 | 2.27 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.27 |
| 3 | 23.48 | 17.97 | 40.55 | 42.20 | 28.68 | 11.78 | 30.35 | 195.0 |
| 4 | 0.00 | 0.00 | 0.00 | 4.52 | 37.43 | 86.80 | 61.32 | 190.1 |
| 5 | 0.00 | 0.00 | 0.00 | 0.00 | 0.93 | 0.00 | 0.00 | 0.93 |
| 6 | 0.00 | 0.00 | 0.00 | 0.65 | 0.00 | 0.00 | 0.00 | 0.65 |
| 7 | 0.00 | 0.00 | 0.00 | 0.00 | 5.07 | 3.13 | 5.80 | 14.00 |
| 8 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.83 | 0.83 |
| 9 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.52 | 1.52 |
| 10 | 0.00 | 0.00 | 0.00 | 1.93 | 0.00 | 0.00 | 0.00 | 1.93 |

*GTD total duration (h)*

| TpID | Mon | Tue | Wed | Thu | Fri | Sat | Sun | SUM |
|---|---|---|---|---|---|---|---|---|
| 1 | 36.73 | 22.52 | 31.85 | 29.77 | 15.47 | 0.00 | 0.00 | 136.3 |
| 2 | 0.50 | 2.27 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.77 |
| 3 | 76.23 | 65.90 | 67.03 | 60.38 | 36.58 | 12.28 | 47.70 | 366.1 |
| 4 | 0.00 | 0.00 | 0.00 | 5.22 | 42.98 | 96.15 | 61.45 | 205.8 |
| 5 | 0.00 | 0.00 | 0.00 | 0.10 | 0.93 | 3.72 | 1.60 | 6.35 |
| 6 | 0.00 | 0.00 | 0.00 | 0.65 | 0.00 | 0.00 | 0.00 | 0.65 |
| 7 | 0.00 | 0.00 | 0.00 | 0.00 | 5.07 | 5.85 | 5.80 | 16.72 |
| 8 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.83 | 0.83 |
| 9 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.52 | 1.52 |
| 10 | 0.00 | 0.00 | 0.00 | 1.93 | 0.00 | 0.00 | 0.00 | 1.93 |

*Proportion of GTD total duration detected*

| TpID | Mon | Tue | Wed | Thu | Fri | Sat | Sun | PROP |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.64 | 0.98 | 1.00 | 0.45 | 0.59 | | | 0.73 |
| 2 | 0.00 | 1.00 | | | | | | 0.82 |
| 3 | 0.31 | 0.27 | 0.60 | 0.70 | 0.78 | 0.96 | 0.64 | 0.53 |
| 4 | | | | 0.87 | 0.87 | 0.90 | 1.00 | 0.92 |
| 5 | | | | 0.00 | 1.00 | 0.00 | 0.00 | 0.15 |
| 6 | | | | 1.00 | | | | 1.00 |
| 7 | | | | | 1.00 | 0.54 | 1.00 | 0.84 |
| 8 | | | | | | | 1.00 | 1.00 |
| 9 | | | | | | | 1.00 | 1.00 |
| 10 | | | | 1.00 | | | | 1.00 |

# 5. Results

## Output tables (example)

| Qsa | Distance d (m) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Time t (s) | 20 | 26.5 | 30 | 40 | 53 | 60 | 70 | 80 | 90 | 100 | 200 |
| 300 | 0.471 | 0.499 | 0.493 | 0.506 | 0.507 | 0.501 | 0.490 | 0.486 | 0.473 | 0.461 | 0.313 |
| 600 | 0.411 | 0.438 | 0.432 | 0.469 | 0.475 | 0.470 | 0.455 | 0.450 | 0.445 | 0.421 | 0.325 |
| 900 | 0.380 | 0.393 | 0.396 | 0.439 | 0.443 | 0.444 | 0.437 | 0.429 | 0.432 | 0.407 | 0.313 |
| 1200 | 0.355 | 0.357 | 0.360 | 0.386 | 0.395 | 0.399 | 0.398 | 0.394 | 0.397 | 0.376 | 0.286 |
| 1500 | 0.335 | 0.328 | 0.338 | 0.357 | 0.366 | 0.372 | 0.384 | 0.378 | 0.379 | 0.367 | 0.305 |
| 1800 | 0.306 | 0.326 | 0.336 | 0.351 | 0.353 | 0.362 | 0.381 | 0.373 | 0.369 | 0.353 | 0.302 |
| 2100 | 0.295 | 0.303 | 0.317 | 0.344 | 0.339 | 0.358 | 0.368 | 0.361 | 0.367 | 0.352 | 0.295 |

| Recall | Distance d (m) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Time t (s) | 20 | 26.5 | 30 | 40 | 53 | 60 | 70 | 80 | 90 | 100 | 200 |
| 300 | 0.697 | 0.737 | 0.745 | 0.731 | 0.728 | 0.728 | 0.719 | 0.720 | 0.698 | 0.658 | 0.503 |
| 600 | 0.586 | 0.617 | 0.629 | 0.648 | 0.649 | 0.648 | 0.644 | 0.654 | 0.645 | 0.603 | 0.488 |
| 900 | 0.514 | 0.522 | 0.548 | 0.577 | 0.581 | 0.581 | 0.576 | 0.597 | 0.589 | 0.561 | 0.453 |
| 1200 | 0.471 | 0.491 | 0.499 | 0.513 | 0.516 | 0.518 | 0.527 | 0.541 | 0.531 | 0.505 | 0.427 |
| 1500 | 0.445 | 0.459 | 0.475 | 0.480 | 0.484 | 0.489 | 0.498 | 0.507 | 0.504 | 0.500 | 0.448 |
| 1800 | 0.414 | 0.450 | 0.461 | 0.462 | 0.464 | 0.485 | 0.489 | 0.497 | 0.484 | 0.473 | 0.437 |
| 2100 | 0.399 | 0.416 | 0.435 | 0.449 | 0.437 | 0.467 | 0.472 | 0.484 | 0.463 | 0.460 | 0.425 |

| Qsu | Distance d (m) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Time t (s) | 20 | 26.5 | 30 | 40 | 53 | 60 | 70 | 80 | 90 | 100 | 200 |
| 300 | 0.992 | 0.996 | 0.996 | 1.000 | 0.996 | 1.000 | 0.996 | 0.996 | 0.996 | 0.998 | 0.994 |
| 600 | 0.987 | 0.995 | 0.995 | 1.000 | 1.000 | 1.000 | 0.994 | 0.994 | 0.994 | 0.991 | 0.995 |
| 900 | 1.000 | 1.000 | 0.993 | 1.000 | 1.000 | 1.000 | 0.993 | 0.993 | 0.993 | 0.995 | 0.993 |
| 1200 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.994 | 0.991 |
| 1500 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.994 | 1.000 |
| 1800 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.993 | 1.000 |
| 2100 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.993 | 1.000 |

| Precision | Distance d (m) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Time t (s) | 20 | 26.5 | 30 | 40 | 53 | 60 | 70 | 80 | 90 | 100 | 200 |
| 300 | 0.441 | 0.459 | 0.470 | 0.428 | 0.416 | 0.413 | 0.407 | 0.392 | 0.372 | 0.351 | 0.285 |
| 600 | 0.624 | 0.591 | 0.610 | 0.594 | 0.579 | 0.585 | 0.552 | 0.559 | 0.556 | 0.517 | 0.416 |
| 900 | 0.728 | 0.699 | 0.722 | 0.695 | 0.673 | 0.661 | 0.641 | 0.671 | 0.664 | 0.636 | 0.489 |
| 1200 | 0.750 | 0.727 | 0.731 | 0.736 | 0.724 | 0.725 | 0.698 | 0.706 | 0.695 | 0.673 | 0.590 |
| 1500 | 0.803 | 0.763 | 0.783 | 0.776 | 0.745 | 0.762 | 0.754 | 0.749 | 0.736 | 0.704 | 0.657 |
| 1800 | 0.828 | 0.785 | 0.810 | 0.790 | 0.775 | 0.786 | 0.757 | 0.777 | 0.760 | 0.744 | 0.674 |
| 2100 | 0.846 | 0.772 | 0.824 | 0.802 | 0.787 | 0.795 | 0.764 | 0.786 | 0.778 | 0.757 | 0.695 |

| Qta | Distance d (m) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Time t (s) | 20 | 26.5 | 30 | 40 | 53 | 60 | 70 | 80 | 90 | 100 | 200 |
| 300 | 0.556 | 0.512 | 0.522 | 0.542 | 0.574 | 0.590 | 0.611 | 0.606 | 0.577 | 0.572 | 0.386 |
| 600 | 0.518 | 0.512 | 0.506 | 0.579 | 0.624 | 0.648 | 0.652 | 0.643 | 0.614 | 0.615 | 0.411 |
| 900 | 0.531 | 0.516 | 0.503 | 0.543 | 0.570 | 0.612 | 0.624 | 0.620 | 0.589 | 0.580 | 0.423 |
| 1200 | 0.529 | 0.514 | 0.493 | 0.566 | 0.593 | 0.619 | 0.629 | 0.621 | 0.593 | 0.586 | 0.385 |
| 1500 | 0.521 | 0.516 | 0.523 | 0.599 | 0.583 | 0.622 | 0.641 | 0.616 | 0.594 | 0.598 | 0.419 |
| 1800 | 0.525 | 0.564 | 0.556 | 0.615 | 0.570 | 0.621 | 0.656 | 0.633 | 0.600 | 0.597 | 0.424 |
| 2100 | 0.526 | 0.596 | 0.558 | 0.616 | 0.582 | 0.633 | 0.659 | 0.640 | 0.602 | 0.603 | 0.416 |

| Fmeasure | Distance d (m) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Time t (s) | 20 | 26.5 | 30 | 40 | 53 | 60 | 70 | 80 | 90 | 100 | 200 |
| 300 | 0.539 | 0.563 | 0.574 | 0.538 | 0.527 | 0.525 | 0.518 | 0.506 | 0.484 | 0.457 | 0.360 |
| 600 | 0.600 | 0.601 | 0.618 | 0.619 | 0.611 | 0.614 | 0.594 | 0.602 | 0.596 | 0.554 | 0.446 |
| 900 | 0.600 | 0.593 | 0.620 | 0.628 | 0.621 | 0.617 | 0.604 | 0.629 | 0.621 | 0.593 | 0.467 |
| 1200 | 0.574 | 0.582 | 0.588 | 0.602 | 0.600 | 0.601 | 0.598 | 0.609 | 0.598 | 0.574 | 0.493 |
| 1500 | 0.568 | 0.568 | 0.587 | 0.591 | 0.583 | 0.592 | 0.596 | 0.601 | 0.593 | 0.580 | 0.528 |
| 1800 | 0.548 | 0.564 | 0.583 | 0.581 | 0.578 | 0.596 | 0.590 | 0.602 | 0.588 | 0.574 | 0.524 |
| 2100 | 0.538 | 0.534 | 0.564 | 0.572 | 0.557 | 0.584 | 0.578 | 0.593 | 0.574 | 0.567 | 0.520 |

| Qti | Distance d (m) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Time t (s) | 20 | 26.5 | 30 | 40 | 53 | 60 | 70 | 80 | 90 | 100 | 200 |
| 300 | 0.452 | 0.551 | 0.612 | 0.664 | 0.685 | 0.719 | 0.788 | 0.785 | 0.792 | 0.817 | 0.831 |
| 600 | 0.492 | 0.585 | 0.669 | 0.667 | 0.728 | 0.748 | 0.784 | 0.789 | 0.792 | 0.799 | 0.837 |
| 900 | 0.549 | 0.608 | 0.649 | 0.705 | 0.713 | 0.751 | 0.777 | 0.782 | 0.775 | 0.808 | 0.838 |
| 1200 | 0.581 | 0.640 | 0.651 | 0.739 | 0.739 | 0.770 | 0.778 | 0.791 | 0.791 | 0.813 | 0.825 |
| 1500 | 0.570 | 0.633 | 0.645 | 0.737 | 0.745 | 0.763 | 0.774 | 0.774 | 0.784 | 0.798 | 0.804 |
| 1800 | 0.602 | 0.636 | 0.651 | 0.729 | 0.745 | 0.759 | 0.770 | 0.774 | 0.803 | 0.809 | 0.805 |
| 2100 | 0.602 | 0.655 | 0.671 | 0.743 | 0.776 | 0.772 | 0.775 | 0.773 | 0.783 | 0.792 | 0.834 |

| Detections | Distance d (m) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Time t (s) | 20 | 26.5 | 30 | 40 | 53 | 60 | 70 | 80 | 90 | 100 | 200 |
| 300 | 115 | 105 | 98 | 101 | 101 | 100 | 99 | 99 | 101 | 102 | 96 |
| 600 | 67 | 65 | 62 | 63 | 62 | 61 | 63 | 63 | 62 | 63 | 63 |
| 900 | 47 | 47 | 45 | 46 | 47 | 48 | 48 | 47 | 47 | 48 | 50 |
| 1200 | 40 | 41 | 40 | 39 | 39 | 39 | 40 | 40 | 41 | 40 | 39 |
| 1500 | 35 | 36 | 36 | 34 | 35 | 35 | 35 | 36 | 36 | 38 | 37 |
| 1800 | 31 | 34 | 33 | 33 | 32 | 33 | 34 | 34 | 34 | 34 | 35 |
| 2100 | 29 | 32 | 31 | 31 | 30 | 32 | 33 | 33 | 32 | 33 | 33 |

- 1. **Averaged** results from 4 *users* → **Algorithms assessment**
- 2. Selection of **best individual dataset** (*User1*)
- 3. Selection of **parameter settings** generating highest **F measure**
- 4. **Characterization** of **stays** and **transitions** from *User1*

# 5. Results

## 1. Determination of visited places

### Algorithms assessment

Best values for each measure and generating parameters

| Algorithm | KANG | | YE | | DBSCAN | |
|---|---|---|---|---|---|---|
| | Parameters | Value | Parameters | Value | Parameters | Value |
| Recall | 30 / 300 | 0.745 | 100 / 300 | 0.718 | 6 / 20 | 0.770 |
| Precision | 20 / 2100 | 0.846 | 26.5 / 3000 | 0.781 | 2 / 120 | 0.663 |
| Fmeasure | 80 / 900 | 0.629 | 100 / 1200 | 0.575 | 18 / 110 | 0.561 |
| Qsa | 53 / 300 | 0.507 | 53 / 300 | 0.490 | 9 / 20 | 0.493 |
| Qsu | Multi | 1.000 | Multi | 1.000 | Multi | 1.000 |
| Qta | 70 / 2100 | 0.659 | 26.5 / 3000 | 0.691 | 2 / 80 | 0.852 |
| Qti | 200 / 900 | 0.838 | 200 / 3000 | 0.796 | 15 / 120 | 0.589 |

➢ **Temporal performance**

- Maximum Qta: **DBSCAN**

  *Accuracy of times detected*

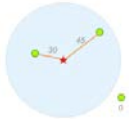

- Maximum Qti: **Kang**

  *83.8% of times detected are correct*

➢ **Spatial performance**

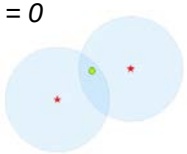
- Maximum Qsa: **Kang**

  *Spatial accuracy of detections (distance/number)*



- Maximum Qsu: **ALL**

  *Cases of detections within overlapping areas = 0*



- **Absolute temporal** performance highly dependant on **spatial** performance
- Without spatial assignment there is no posible temporal assignment

**Performance** of the clustering → **Confusion matrix** metrics → **F measure**

# 5. Results

## 1. Determination of visited places

$$F\ measure = \frac{2 * (Precision * Recall)}{Precision + Recall}$$

➢ **Clustering performance**

| Best F measure and associated measures | | | |
|---|---|---|---|
| **Algorithm** | **KANG** | **YE** | **DBSCAN** |
| **Parameters (d/t)** | **80 / 900** | **100 / 1200** | **18 / 110** |
| | **Value** | **Value** | **Value** |
| **Recall** | 0.597 | 0.525 | 0.630 |
| **Precision** | 0.671 | 0.642 | 0.508 |
| **Fmeasure** | **0.629** | **0.575** | **0.561** |
| **Detections** | 47 | 45 | 72 |
| **Qsa** | 0.432 | 0.391 | 0.459 |
| **Qsu** | 0.993 | 1.000 | 0.994 |
| **Qta** | 0.589 | 0.537 | 0.621 |
| **Qti** | 0.775 | 0.671 | 0.515 |

➢ **Best individual performance** *(User 1)*

| Best F measure and associated measures | | | |
|---|---|---|---|
| **Algorithm** | **KANG** | **YE** | **DBSCAN** |
| **Parameters** | **53 / 900** | **100 / 1200** | **6 / 120** |
| | **Value** | **Value** | **Value** |
| **Recall** | 0.722 | 0.639 | 0.667 |
| **Precision** | 0.765 | 0.719 | 0.800 |
| **Fmeasure** | **0.735** | **0.676** | **0.727** |
| **Detections** | 36 | 32 | 38 |
| **Qsa** | 0.554 | 0.505 | 0.530 |
| **Qsu** | 1.000 | 1.000 | 0.974 |
| **Qta** | 0.483 | 0.375 | 0.486 |
| **Qti** | 0.815 | 0.913 | 0.567 |

- Best F measure: **Kang**
- Best individual results: **Kang** *(User1)*

# 5. Results

## 2. Characterization of stays and transitions

➢ **Comparison of the extraction** (User 1)

Results for the best param. setting for each algorithm

| Algorithm | KANG | YE | DBSCAN |
|---|---|---|---|
| Parameters | 53 / 900 | 100 / 1200 | 6 / 120 |
| | Value | Value | Value |
| Recall | 0.722 | 0.639 | 0.667 |
| Precision | 0.765 | 0.719 | 0.800 |
| Fmeasure | **0.735** | **0.676** | **0.727** |
| Detections | 36 | 32 | 38 |
| Qsa | 0.554 | 0.505 | 0.530 |
| Qsu | 1.000 | 1.000 | 0.974 |
| Qta | 0.483 | 0.375 | 0.486 |
| Qti | 0.815 | 0.913 | 0.567 |
| StayT_ext | 0.619 | 0.175 | 0.468 |
| TranT_ext | 0.493 | 0.295 | 0.373 |
| StRecall | 0.600 | 0.317 | 0.450 |
| StPrecision | 0.684 | 0.471 | 0.600 |
| StFmeas | 0.639 | 0.379 | 0.514 |
| TrRecall | 0.568 | 0.331 | 0.374 |
| TrPrecision | 0.594 | 0.387 | 0.452 |
| TrFmeas | 0.581 | 0.357 | 0.409 |

Stay and Transition time extracted

Stay detection quality

Transition detection quality

**Kang**

Best performance

# 5. Results

## 2. Characterization of stays and transitions

**Kang** *(User1)* **Example of movement behaviour profiling**

Number of stays at each tP for each week day

*Detected Occurrences*

| TpID | Mon | Tue | Wed | Thu | Fri | Sat | Sun | SUM |
|---|---|---|---|---|---|---|---|---|
| 1 | 3 | 4 | 4 | 2 | 2 | 0 | 0 | 15 |
| 2 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| 3 | 4 | 3 | 6 | 8 | 7 | 1 | 4 | 33 |
| 4 | 0 | 0 | 0 | 1 | 10 | 14 | 12 | 37 |
| 5 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| 6 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| 7 | 0 | 0 | 0 | 0 | 2 | 1 | 2 | 5 |
| 8 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 9 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 10 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| 11 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| 12 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| 13 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| 14 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 15 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| 16 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| 17 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| 18 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 19 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 20 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 21 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 22 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 23 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 24 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 25 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 26 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 27 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 28 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 29 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| SUM | 8 | 9 | 11 | 13 | 23 | 20 | 24 | 108 |

*GTD Occurrences*

| TpID | Mon | Tue | Wed | Thu | Fri | Sat | Sun | SUM |
|---|---|---|---|---|---|---|---|---|
| 1 | 8 | 5 | 4 | 6 | 6 | 0 | 0 | 29 |
| 2 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 2 |
| 3 | 11 | 10 | 11 | 12 | 8 | 2 | 7 | 61 |
| 4 | 0 | 0 | 0 | 3 | 11 | 16 | 13 | 43 |
| 5 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 4 |
| 6 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| 7 | 0 | 0 | 0 | 0 | 2 | 2 | 2 | 6 |
| 8 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 9 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 10 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| 11 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 3 |
| 12 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| 13 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| 14 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 |
| 15 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| 16 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| 17 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| 18 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 19 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 20 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 21 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 22 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 23 | 1 | 3 | 2 | 2 | 0 | 0 | 0 | 8 |
| 24 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| 25 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 3 |
| 26 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| 27 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 28 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 29 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| 30 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| SUM | 24 | 22 | 21 | 28 | 30 | 26 | 29 | 180 |

*Proportion of GTD Occurrences detected*

| TpID | Mon | Tue | Wed | Thu | Fri | Sat | Sun | PROP | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.38 | 0.80 | 1.00 | 0.33 | 0.33 | | | 0.52 | Work |
| 2 | 0.00 | 1.00 | | | | | | 0.50 | |
| 3 | 0.36 | 0.30 | 0.55 | 0.67 | 0.88 | 0.50 | 0.57 | 0.54 | Home1 |
| 4 | | | | 0.33 | 0.91 | 0.88 | 0.92 | 0.86 | Home2 |
| 5 | | | | 0.00 | 1.00 | 0.00 | 0.00 | 0.25 | |
| 6 | | | | 1.00 | | | | 1.00 | |
| 7 | | | | | 1.00 | 0.50 | 1.00 | 0.83 | |
| 8 | | | | | | | 1.00 | 1.00 | |
| 9 | | | | | | | 1.00 | 1.00 | |
| 10 | | | | 1.00 | | | | 1.00 | |
| 11 | | 1.00 | 0.00 | 0.00 | | | | 0.33 | |
| 12 | | | 1.00 | | | | | 1.00 | |
| 13 | | | | | 1.00 | | | 1.00 | |
| 14 | | | | | 0.00 | | | 0.00 | |
| 15 | | | | | | 1.00 | | 1.00 | |
| 16 | | | | | | 1.00 | | 1.00 | |
| 17 | | | | | | 1.00 | | 1.00 | |
| 18 | | | | | | | 1.00 | 1.00 | |
| 19 | | | | | | | 1.00 | 1.00 | |
| 20 | 1.00 | | | | | | | 1.00 | |
| 21 | 0.00 | | | | | | | 0.00 | |
| 22 | 0.00 | | | | | | | 0.00 | |
| 23 | 0.00 | 0.00 | 0.00 | 0.00 | | | | 0.00 | |
| 24 | | 0.00 | | | | | | 0.00 | |
| 25 | | 0.00 | 0.00 | 0.00 | | | | 0.00 | |
| 26 | | | 0.00 | | | | | 0.00 | |
| 27 | | | | | | | 1.00 | 1.00 | |
| 28 | | | | | | | 1.00 | 1.00 | |
| 29 | | | | | | 1.00 | | 1.00 | |
| 30 | | | | | | 0.00 | | 0.00 | |
| PROP | 0.33 | 0.41 | 0.52 | 0.46 | 0.77 | 0.77 | 0.83 | 0.60 | |

3 most stayed places

>83% time


Mondays worst detection

Weekends best detection

# 5. Results

## 2. Characterization of stays and transitions

**Kang** *(User1)* **Example of movement behaviour profiling**

Stays duration at each tagged place for each weekday

*Detected total duration (h)*

| TpID | Mon | Tue | Wed | Thu | Fri | Sat | Sun | SUM |
|---|---|---|---|---|---|---|---|---|
| 1 | 23.48 | 22.02 | 31.85 | 13.48 | 9.10 | 0.00 | 0.00 | 99.93 |
| 2 | 0.00 | 2.27 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.27 |
| 3 | 23.48 | 17.97 | 40.55 | 42.20 | 28.68 | 11.78 | 30.35 | 195.0 |
| 4 | 0.00 | 0.00 | 0.00 | 4.52 | 37.43 | 86.80 | 61.32 | 190.1 |
| 5 | 0.00 | 0.00 | 0.00 | 0.00 | 0.93 | 0.00 | 0.00 | 0.93 |
| 6 | 0.00 | 0.00 | 0.00 | 0.65 | 0.00 | 0.00 | 0.00 | 0.65 |
| 7 | 0.00 | 0.00 | 0.00 | 0.00 | 5.07 | 3.13 | 5.80 | 14.00 |
| 8 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.83 | 0.83 |
| 9 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.52 | 1.52 |
| 10 | 0.00 | 0.00 | 0.00 | 1.93 | 0.00 | 0.00 | 0.00 | 1.93 |
| 11 | 0.00 | 8.70 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 8.70 |
| 12 | 0.00 | 0.00 | 3.42 | 0.00 | 0.00 | 0.00 | 0.00 | 3.42 |
| 13 | 0.00 | 0.00 | 0.00 | 0.00 | 1.40 | 0.00 | 0.00 | 1.40 |
| 14 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 15 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 0.00 | 1.00 |
| 16 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.70 | 0.00 | 0.70 |
| 17 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.48 | 0.00 | 2.48 |
| 18 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.17 | 0.17 |
| 19 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.32 | 0.32 |
| 20 | 1.27 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.27 |
| 21 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 22 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 23 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 24 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 25 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 26 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 27 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.83 | 1.83 |
| 28 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.22 | 1.22 |
| 29 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.73 | 0.00 | 0.73 |
| 30 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| SUM | 48.2 | 50.9 | 75.8 | 62.8 | 82.6 | 106.6 | 103.3 | 530.4 |

*GTD total duration (h)*

| TpID | Mon | Tue | Wed | Thu | Fri | Sat | Sun | SUM |
|---|---|---|---|---|---|---|---|---|
| 1 | 36.73 | 22.52 | 31.85 | 29.77 | 15.47 | 0.00 | 0.00 | 136.3 |
| 2 | 0.50 | 2.27 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.77 |
| 3 | 76.23 | 65.90 | 67.03 | 60.38 | 36.58 | 12.28 | 47.70 | 366.1 |
| 4 | 0.00 | 0.00 | 0.00 | 5.22 | 42.98 | 96.15 | 61.45 | 205.8 |
| 5 | 0.00 | 0.00 | 0.00 | 0.10 | 0.93 | 3.72 | 1.60 | 6.35 |
| 6 | 0.00 | 0.00 | 0.00 | 0.65 | 0.00 | 0.00 | 0.00 | 0.65 |
| 7 | 0.00 | 0.00 | 0.00 | 0.00 | 5.07 | 5.85 | 5.80 | 16.72 |
| 8 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.83 | 0.83 |
| 9 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.52 | 1.52 |
| 10 | 0.00 | 0.00 | 0.00 | 1.93 | 0.00 | 0.00 | 0.00 | 1.93 |
| 11 | 0.00 | 8.70 | 9.20 | 9.38 | 0.00 | 0.00 | 0.00 | 27.28 |
| 12 | 0.00 | 0.00 | 3.42 | 0.00 | 0.00 | 0.00 | 0.00 | 3.42 |
| 13 | 0.00 | 0.00 | 0.00 | 0.00 | 1.40 | 0.00 | 0.00 | 1.40 |
| 14 | 0.00 | 0.00 | 0.00 | 0.00 | 0.50 | 0.00 | 0.00 | 0.50 |
| 15 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.00 | 0.00 | 1.00 |
| 16 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.70 | 0.00 | 0.70 |
| 17 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.48 | 0.00 | 2.48 |
| 18 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.17 | 0.17 |
| 19 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.32 | 0.32 |
| 20 | 1.27 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.27 |
| 21 | 0.80 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.80 |
| 22 | 0.22 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.22 |
| 23 | 9.87 | 14.37 | 10.88 | 10.58 | 0.00 | 0.00 | 0.00 | 45.70 |
| 24 | 0.00 | 4.78 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 4.78 |
| 25 | 0.00 | 4.28 | 8.32 | 7.55 | 0.00 | 0.00 | 0.00 | 20.15 |
| 26 | 0.00 | 0.00 | 3.13 | 0.00 | 0.00 | 0.00 | 0.00 | 3.13 |
| 27 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.83 | 1.83 |
| 28 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.22 | 1.22 |
| 29 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.73 | 0.00 | 0.73 |
| 30 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.35 | 0.00 | 0.35 |
| SUM | 125.6 | 122.8 | 133.8 | 125.6 | 102.9 | 123.3 | 122.4 | 856.5 |

*Proportion of GTD total duration detected*

| TpID | Mon | Tue | Wed | Thu | Fri | Sat | Sun | PROP | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.64 | 0.98 | 1.00 | 0.45 | 0.59 | | | 0.73 | Work |
| 2 | 0.00 | 1.00 | | | | | | 0.82 | |
| 3 | 0.31 | 0.27 | 0.60 | 0.70 | 0.78 | 0.96 | 0.64 | 0.53 | Home1 |
| 4 | | | | 0.87 | 0.87 | 0.90 | 1.00 | 0.92 | Home2 |
| 5 | | | | 0.00 | 1.00 | 0.00 | 0.00 | 0.15 | |
| 6 | | | | 1.00 | | | | 1.00 | |
| 7 | | | | | 1.00 | 0.54 | 1.00 | 0.84 | |
| 8 | | | | | | | 1.00 | 1.00 | |
| 9 | | | | | | | 1.00 | 1.00 | |
| 10 | | | | 1.00 | | | | 1.00 | |
| 11 | | 1.00 | 0.00 | 0.00 | | | | 0.32 | |
| 12 | | | 1.00 | | | | | 1.00 | |
| 13 | | | | | 1.00 | | | 1.00 | |
| 14 | | | | | 0.00 | | | 0.00 | |
| 15 | | | | | | 1.00 | | 1.00 | |
| 16 | | | | | | 1.00 | | 1.00 | |
| 17 | | | | | | 1.00 | | 1.00 | |
| 18 | | | | | | | 1.00 | 1.00 | |
| 19 | | | | | | | 1.00 | 1.00 | |
| 20 | 1.00 | | | | | | | 1.00 | |
| 21 | 0.00 | | | | | | | 0.00 | |
| 22 | 0.00 | | | | | | | 0.00 | |
| 23 | 0.00 | 0.00 | 0.00 | 0.00 | | | | 0.00 | |
| 24 | | 0.00 | | | | | | 0.00 | |
| 25 | | 0.00 | 0.00 | 0.00 | | | | 0.00 | |
| 26 | | | 0.00 | | | | | 0.00 | |
| 27 | | | | | | | 1.00 | 1.00 | |
| 28 | | | | | | | 1.00 | 1.00 | |
| 29 | | | | | | 1.00 | | 1.00 | |
| 30 | | | | | | 0.00 | | 0.00 | |
| PROP | 0.38 | 0.41 | 0.57 | 0.50 | 0.80 | 0.87 | 0.84 | 0.62 | |

3 most stayed places

>83% time


Mondays worst detection

Weekends best detection

# Kang *(User1)*

**Transitions between tagged places for each weekday**

***Detected total duration (h)***

| Tran | Mon | Tue | Wed | Thu | Fri | Sat | Sun | SUM |
|---|---|---|---|---|---|---|---|---|
| 01-01 | 0.00 | 0.15 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.15 |
| 01-02 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 01-03 | 0.38 | 0.35 | 0.80 | 0.30 | 0.50 | 0.00 | 0.00 | 2.33 |
| 01-31 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 02-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 02-03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 03-01 | 0.42 | 0.12 | 0.13 | 0.38 | 0.52 | 0.00 | 0.00 | 1.57 |
| 03-03 | 0.82 | 1.45 | 0.33 | 0.30 | 0.00 | 0.00 | 0.00 | 2.90 |
| 03-04 | 0.00 | 0.00 | 0.00 | 0.00 | 2.82 | 0.00 | 0.00 | 2.82 |
| 03-10 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 03-11 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 03-12 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 03-13 | 0.00 | 0.00 | 0.00 | 0.00 | 1.53 | 0.00 | 0.00 | 1.53 |
| 03-19 | 0.57 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.57 |
| 03-26 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.70 | 1.70 |
| 04-03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.37 | 2.37 |
| 04-04 | 0.00 | 0.00 | 0.00 | 0.00 | 2.70 | 4.13 | 1.87 | 8.70 |
| 04-05 | 0.00 | 0.00 | 0.00 | 0.00 | 0.55 | 0.10 | 0.10 | 0.75 |
| 04-06 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 04-07 | 0.00 | 0.00 | 0.00 | 0.00 | 0.20 | 0.12 | 0.12 | 0.43 |
| 04-08 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.12 | 0.12 |
| 04-09 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.83 | 0.83 |
| 04-14 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.67 | 0.00 | 0.67 |
| 04-16 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.13 | 0.00 | 0.13 |
| 04-17 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 04-28 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.27 | 0.00 | 0.27 |
| 05-04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.10 | 0.00 | 0.00 | 0.10 |
| 06-04 | 0.00 | 0.00 | 0.00 | 0.03 | 0.00 | 0.00 | 0.00 | 0.03 |
| 07-04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.17 | 0.10 | 0.17 | 0.43 |
| 08-04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.15 | 2.15 |
| 09-04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.62 | 0.62 |
| 10-03 | 0.00 | 0.00 | 0.00 | 0.27 | 0.00 | 0.00 | 0.00 | 0.27 |
| 11-03 | 0.00 | 0.43 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.43 |
| 12-03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 13-04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.15 | 0.00 | 0.00 | 0.15 |
| 14-15 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 15-04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.55 | 0.00 | 1.55 |
| 16-04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.17 | 0.00 | 0.17 |
| 17-18 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 18-04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.33 | 1.33 |
| 19-20 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 20-21 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 21-22 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 22-23 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 22-24 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 23-22 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 24-22 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 24-25 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 25-22 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 26-27 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.12 | 0.12 |
| 27-03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.05 | 1.05 |
| 28-29 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 29-04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 31-01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| SUM | 2.18 | 2.50 | 1.27 | 1.28 | 9.23 | 7.23 | 12.53 | 36.23 |

***GTD total duration (h)***

| Tran | Mon | Tue | Wed | Thu | Fri | Sat | Sun | SUM |
|---|---|---|---|---|---|---|---|---|
| 01-01 | 0.25 | 0.15 | 0.00 | 0.28 | 0.18 | 0.00 | 0.00 | 0.87 |
| 01-02 | 0.27 | 1.92 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.18 |
| 01-03 | 0.50 | 0.35 | 0.92 | 0.60 | 0.50 | 0.00 | 0.00 | 2.87 |
| 01-31 | 0.00 | 0.00 | 0.00 | 0.00 | 0.10 | 0.00 | 0.00 | 0.10 |
| 02-01 | 2.60 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.60 |
| 02-03 | 0.00 | 0.15 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.15 |
| 03-01 | 0.72 | 0.35 | 0.47 | 0.53 | 0.52 | 0.00 | 0.00 | 2.58 |
| 03-03 | 0.82 | 1.45 | 0.33 | 0.30 | 0.00 | 0.72 | 0.00 | 3.62 |
| 03-04 | 0.00 | 0.00 | 0.00 | 1.25 | 4.95 | 0.00 | 0.00 | 6.20 |
| 03-10 | 0.00 | 0.00 | 0.00 | 0.62 | 0.00 | 0.00 | 0.00 | 0.62 |
| 03-11 | 0.00 | 0.32 | 0.12 | 0.28 | 0.00 | 0.00 | 0.00 | 0.72 |
| 03-12 | 0.00 | 0.00 | 0.55 | 0.00 | 0.00 | 0.00 | 0.00 | 0.55 |
| 03-13 | 0.00 | 0.00 | 0.00 | 0.00 | 1.53 | 0.00 | 0.00 | 1.53 |
| 03-19 | 0.57 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.57 |
| 03-26 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.70 | 1.70 |
| 04-03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 5.88 | 5.88 |
| 04-04 | 0.00 | 0.00 | 0.00 | 0.00 | 2.70 | 4.28 | 1.87 | 8.85 |
| 04-05 | 0.00 | 0.00 | 0.00 | 0.10 | 0.55 | 0.10 | 0.10 | 0.85 |
| 04-06 | 0.00 | 0.00 | 0.00 | 0.05 | 0.00 | 0.00 | 0.00 | 0.05 |
| 04-07 | 0.00 | 0.00 | 0.00 | 0.00 | 0.20 | 0.12 | 0.12 | 0.43 |
| 04-08 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.12 | 0.12 |
| 04-09 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.83 | 0.83 |
| 04-14 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.67 | 0.00 | 0.67 |
| 04-16 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.13 | 0.00 | 0.13 |
| 04-17 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.87 | 3.87 |
| 04-28 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.27 | 0.00 | 0.27 |
| 05-04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.10 | 0.10 | 0.12 | 0.48 |
| 06-04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 | 0.00 | 0.00 | 0.03 |
| 07-04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.17 | 0.13 | 0.17 | 0.47 |
| 08-04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.15 | 2.15 |
| 09-04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.62 | 0.62 |
| 10-03 | 0.00 | 0.00 | 0.00 | 0.27 | 0.00 | 0.00 | 0.00 | 0.27 |
| 11-03 | 0.00 | 0.43 | 0.00 | 0.27 | 0.00 | 0.00 | 0.00 | 0.70 |
| 12-03 | 0.00 | 0.00 | 0.15 | 0.00 | 0.00 | 0.00 | 0.00 | 0.15 |
| 13-04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.15 | 0.00 | 0.00 | 0.15 |
| 14-15 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.88 | 0.00 | 0.88 |
| 15-04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.55 | 0.00 | 1.55 |
| 16-04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.17 | 0.00 | 0.17 |
| 17-18 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.48 | 1.48 |
| 18-04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.33 | 1.33 |
| 19-20 | 0.93 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.93 |
| 20-21 | 3.10 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.10 |
| 21-22 | 0.42 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.42 |
| 22-23 | 0.00 | 0.10 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.10 |
| 22-24 | 0.00 | 0.13 | 0.17 | 0.20 | 0.00 | 0.00 | 0.00 | 0.50 |
| 23-22 | 0.00 | 0.15 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.15 |
| 24-22 | 0.00 | 0.18 | 0.00 | 0.17 | 0.00 | 0.00 | 0.00 | 0.35 |
| 24-25 | 0.00 | 0.00 | 0.67 | 0.00 | 0.00 | 0.00 | 0.00 | 0.67 |
| 25-22 | 0.00 | 0.00 | 0.83 | 0.00 | 0.00 | 0.00 | 0.00 | 0.83 |
| 26-27 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.12 | 0.12 |
| 27-03 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.05 | 1.05 |
| 28-29 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.55 | 0.00 | 0.55 |
| 29-04 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.05 | 0.00 | 0.05 |
| 31-01 | 0.00 | 0.00 | 0.00 | 0.00 | 5.42 | 0.00 | 0.00 | 5.42 |
| SUM | 10.17 | 5.68 | 4.20 | 5.05 | 17.07 | 9.73 | 21.57 | 73.47 |

***Proportion of GTD total duration detected***

| Tran | Mon | Tue | Wed | Thu | Fri | Sat | Sun | PROP |
|---|---|---|---|---|---|---|---|---|
| 01-01 | 0.00 | 1.00 | | 0.00 | 0.00 | | | 0.17 |
| 01-02 | 0.00 | 0.00 | | | | | | 0.00 |
| 01-03 | 0.77 | 1.00 | 0.87 | 0.50 | 1.00 | | | 0.81 |
| 01-31 | | | | | 0.00 | | | 0.00 |
| 02-01 | 0.00 | | | | | | | 0.00 |
| 02-03 | | 0.00 | | | | | | 0.00 |
| 03-01 | 0.58 | 0.33 | 0.29 | 0.72 | 1.00 | | | 0.61 |
| 03-03 | 1.00 | 1.00 | 1.00 | 1.00 | | 0.00 | | 0.80 |
| 03-04 | | | | 0.00 | 0.57 | | | 0.45 |
| 03-10 | | | | 0.00 | | | | 0.00 |
| 03-11 | | 0.00 | 0.00 | 0.00 | | | | 0.00 |
| 03-12 | | | 0.00 | | | | | 0.00 |
| 03-13 | | | | | 1.00 | | | 1.00 |
| 03-19 | 1.00 | | | | | | | 1.00 |
| 03-26 | | | | | | | 1.00 | 1.00 |
| 04-03 | | | | | | | 0.40 | 0.40 |
| 04-04 | | | | | 1.00 | 0.96 | 1.00 | 0.98 |
| 04-05 | | | | 0.00 | 1.00 | 1.00 | 1.00 | 0.88 |
| 04-06 | | | | 0.00 | | | | 0.00 |
| 04-07 | | | | | 1.00 | 1.00 | 1.00 | 1.00 |
| 04-08 | | | | | | | 1.00 | 1.00 |
| 04-09 | | | | | | | 1.00 | 1.00 |
| 04-14 | | | | | | 1.00 | | 1.00 |
| 04-16 | | | | | | 1.00 | | 1.00 |
| 04-17 | | | | | | | 0.00 | 0.00 |
| 04-28 | | | | | | 1.00 | | 1.00 |
| 05-04 | | | | 0.00 | 1.00 | 0.00 | 0.00 | 0.21 |
| 06-04 | | | | 1.00 | | | | 1.00 |
| 07-04 | | | | | 1.00 | 0.75 | 1.00 | 0.93 |
| 08-04 | | | | | | | 1.00 | 1.00 |
| 09-04 | | | | | | | 1.00 | 1.00 |
| 10-03 | | | | 1.00 | | | | 1.00 |
| 11-03 | | 1.00 | | 0.00 | | | | 0.62 |
| 12-03 | | | 0.00 | | | | | 0.00 |
| 13-04 | | | | | 1.00 | | | 1.00 |
| 14-15 | | | | | | 0.00 | | 0.00 |
| 15-04 | | | | | | 1.00 | | 1.00 |
| 16-04 | | | | | | 1.00 | | 1.00 |
| 17-18 | | | | | | | 0.00 | 0.00 |
| 18-04 | | | | | | | 1.00 | 1.00 |
| 19-20 | 0.00 | | | | | | | 0.00 |
| 20-21 | 0.00 | | | | | | | 0.00 |
| 21-22 | 0.00 | | | | | | | 0.00 |
| 22-23 | | 0.00 | | | | | | 0.00 |
| 22-24 | | 0.00 | 0.00 | 0.00 | | | | 0.00 |
| 23-22 | | 0.00 | | | | | | 0.00 |
| 24-22 | | 0.00 | | 0.00 | | | | 0.00 |
| 24-25 | | | 0.00 | | | | | 0.00 |
| 25-22 | | | 0.00 | | | | | 0.00 |
| 26-27 | | | | | | | 1.00 | 1.00 |
| 27-03 | | | | | | | 1.00 | 1.00 |
| 28-29 | | | | | | 0.00 | | 0.00 |
| 29-04 | | | | | | 0.00 | | 0.00 |
| 31-01 | | | | | 0.00 | | | 0.00 |
| PROP | 0.21 | 0.44 | 0.3 | 0.25 | 0.54 | 0.74 | 0.58 | 0.49 |

**Work → Home1**

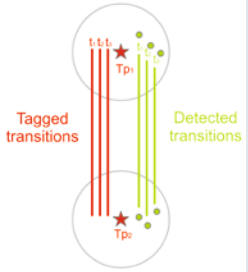
**Home1 → Work**

**Home1 → Home1**

**Home1 → Home2**

**Home2 → Home1**

**Home2 → Home2**




**Fri.**: Long time spent moving **Home1 → Home2**

**Sun.**: Long time spent moving **Home2 → Home1**

**Sat.**: Long time spent moving around **Home2**

**Trips by plane**

Wednesdays worst detection

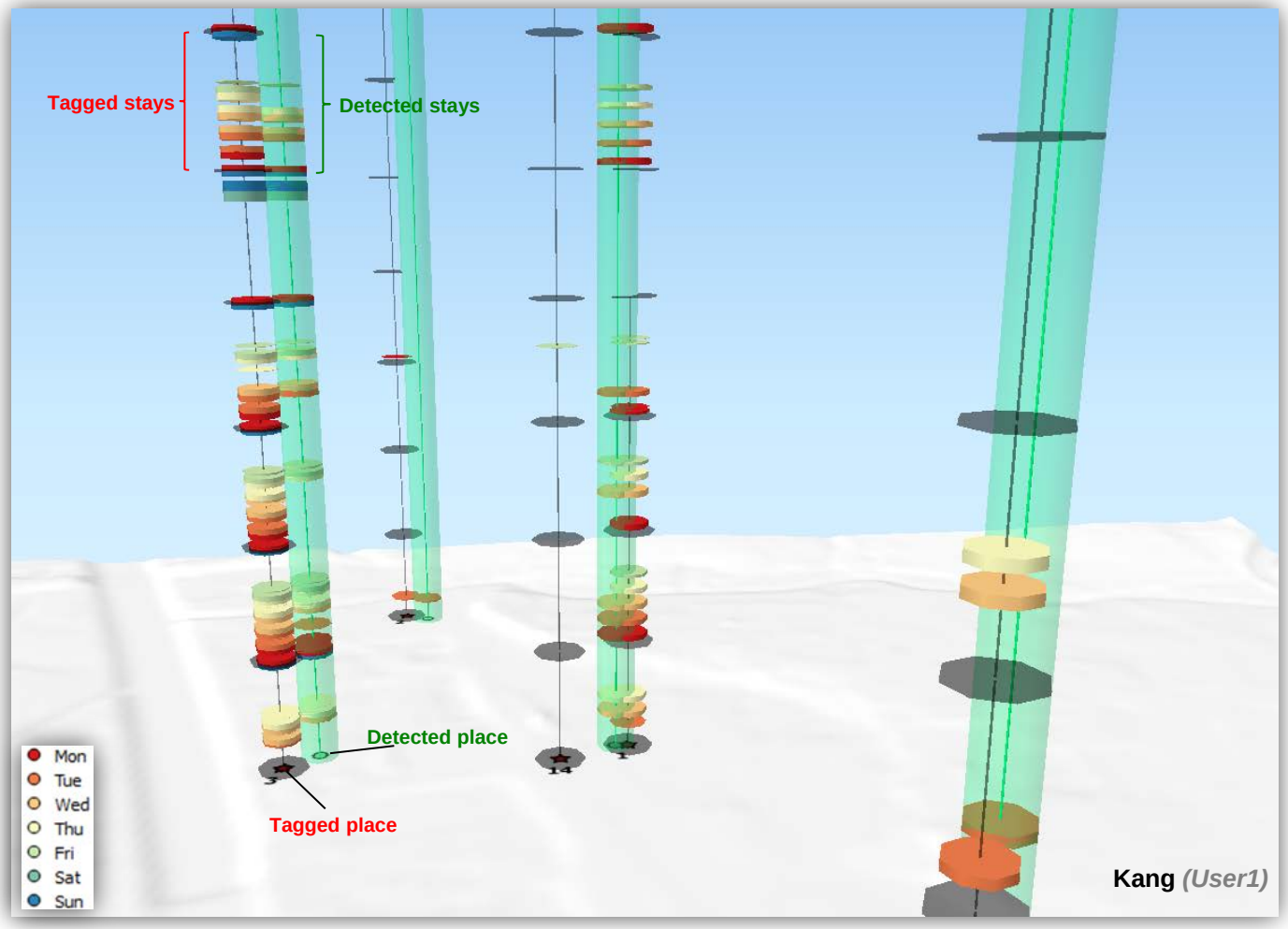
Weekends best detection

# 5. Results

## 2. Characterization of stays and transitions

- Tagged stays and detected stays
- Green cylinder at detected places

➢ **Visualization of movement behaviour**



# 6. Conclusions

- **Incremental approach** best performance**: detection** of **visited places** and **extraction** of **stays/transitions:**
  - User‘s typical **stay length** influences optimum **time** parameter
  - Algorithm **runtime** → implementation on mobile applications
- ***Incremental* + *density-based* poor** results → GTD dataset structure
- ***Density-based*** approach **intermediate** results:
  - Parameter settings highly dependant on dataset structure.
  - Clustering requires whole dataset and demands higher computing resources.

- User‘s **movement behaviour** profiling.
- **Visit** *duration* / *weekday* basic info for **stays** and **transition** characterization.
- **Transitions** require also *origin* / *destination*. *Euclidean distance* / *speed* → detection **anomalous situations** and **errors**

**Future work**

- **Presence probabilities** with **Markov Models**
- **Means of transport** → dynamic adaptation of Kang‘s ***distance***
- Additional **pre-processing** of input → improve **combined approach** performance

**THANK YOU VERY MUCH FOR YOUR ATTENTION !**

**Muchas gracias por su atención !**

**And, thank you very much:**

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