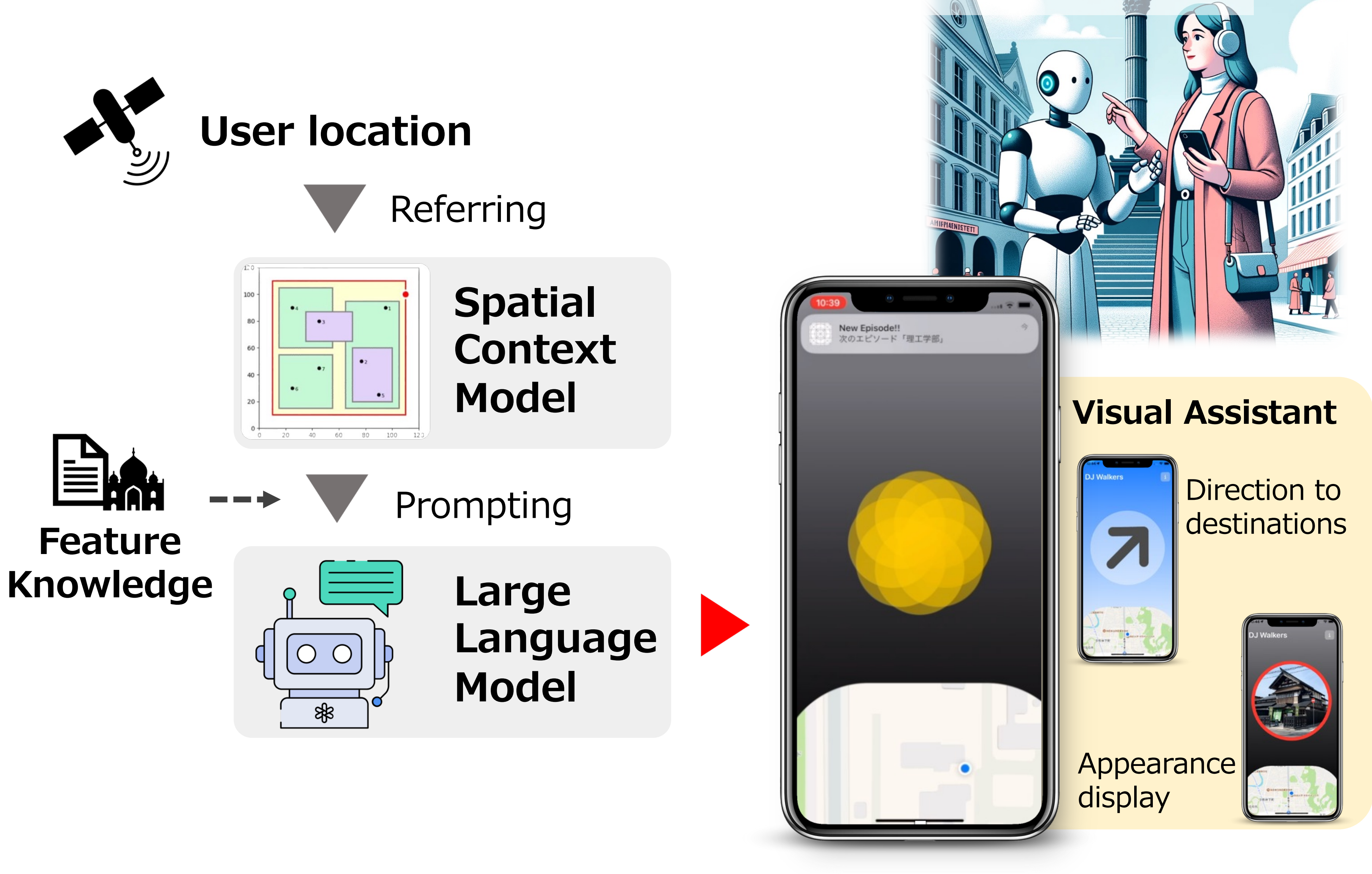
7th ACM SIGSPATIAL Workshop on Location-based Recommendations,
Geosocial Networks and Geoadvertising

Adaptable Data-Driven Geofences for Notifying Points of Interest Using Tourists' GPS Trajectories

Iori Sasaki, Masatoshi Arikawa, Min Lu, Ryo Sato, and Tomihiro Utsumi

Akita University, Japan

DJ Walkers delivers continuous and natural regional stories, following the footsteps of tourists.

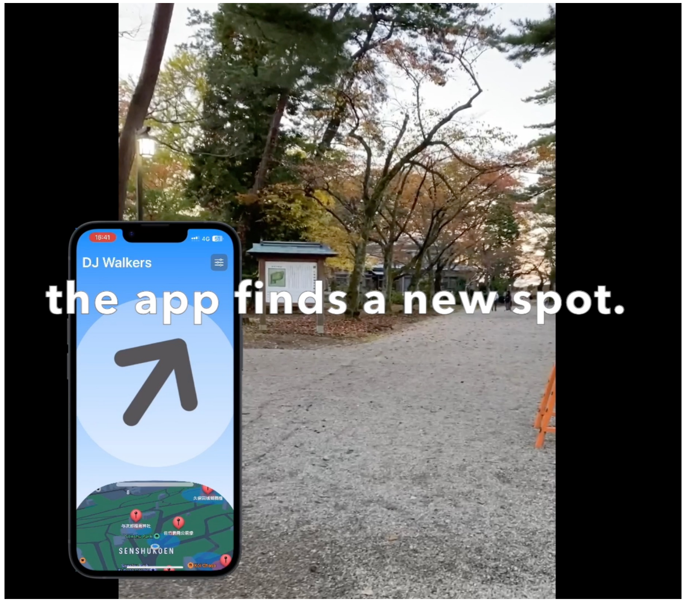


Realization of the mobile app: DJ Walkers

- **Geofencing with circular geofences for recognizing user-feature relations**

Two types:
- Red: nearby geofencing
- Blue: staying geofencing

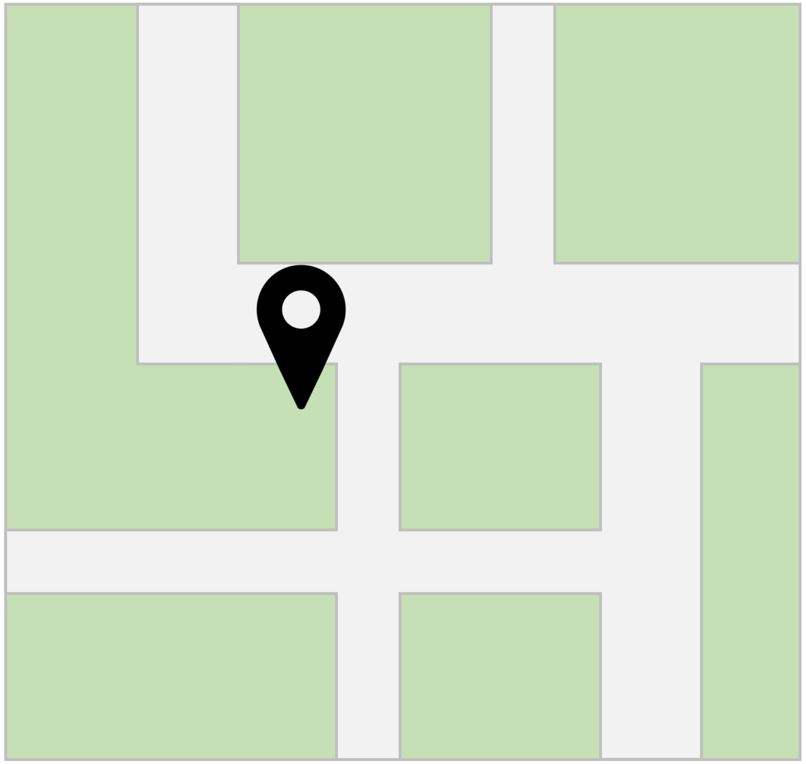
Target of this presentation: POI notifiers



It sends messages or alerts when users are near POIs or passing by them.

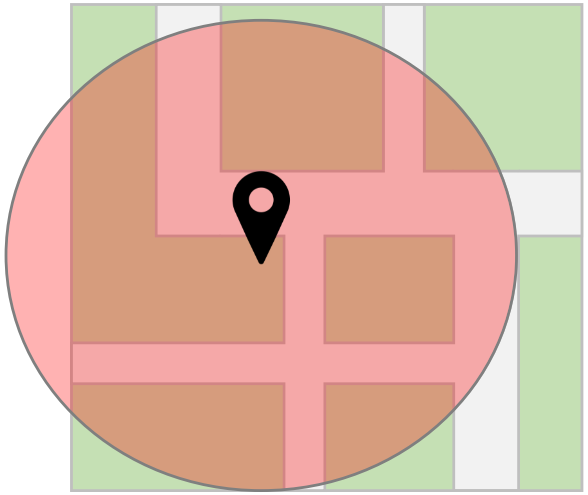
It encourages users to discover and visit POIs.

Where should we set a geofence for good POI notifiers?



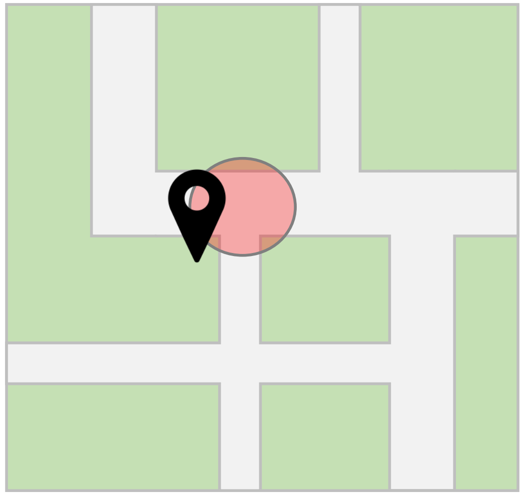
Answer?:

A larger geofence, which would cover a more extensive area



Problem of location relevance

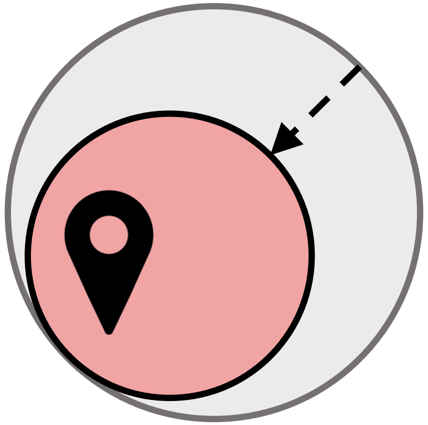
A precise geofence based on heuristic estimations of tourist flows



Problem of user coverage rate

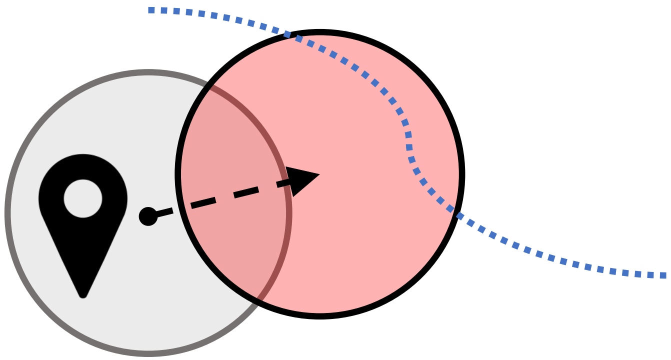
To avoid notification about places that are unnecessarily far from current user locations:

Minimize the distances from the boundaries of geofences to POIs.



To avoid setting geofences in places where few users cross or cannot enter due to walls and rivers:

Maximize the number of covered users.



Our Challenge: Geofence Design

Reliability

Inappropriate activation/ Inactivation

Scalability

Labor-intensive task

Data-driven geofence design that can autonomously optimize location-based services.

Genetic Algorithm – a meta heuristic technique

Input data

$D = (Tr_1, Tr_2, \dots, Tr_m)$

$poi = (x_0, y_0, a)$

Hyper parameters

r_{scan}: scanning range

cr_{limit}: user coverage rate

$CircularRangeQuery(D, poi, r_{scan})$

↓ D_{sub}

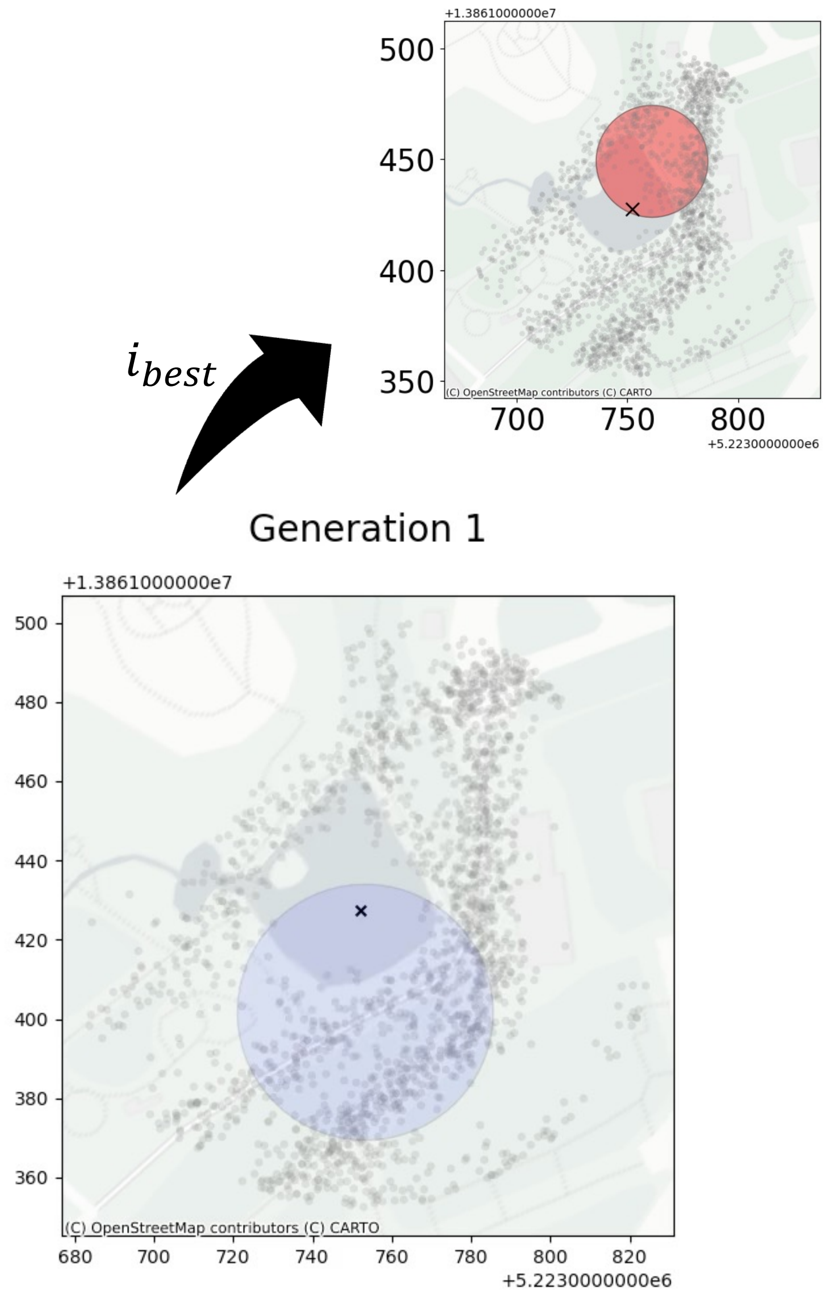
$OptimizeFlexibleCGFWithGA$

- $\underline{CreateIndividual(poi, r_{scan})}$
- $\underline{EvaluateFitness(D_{sub}, poi, cr_{limit})}$
- $Selection()$
- $Crossover()$
- $Mutation()$
- $SelectNextGeneration()$

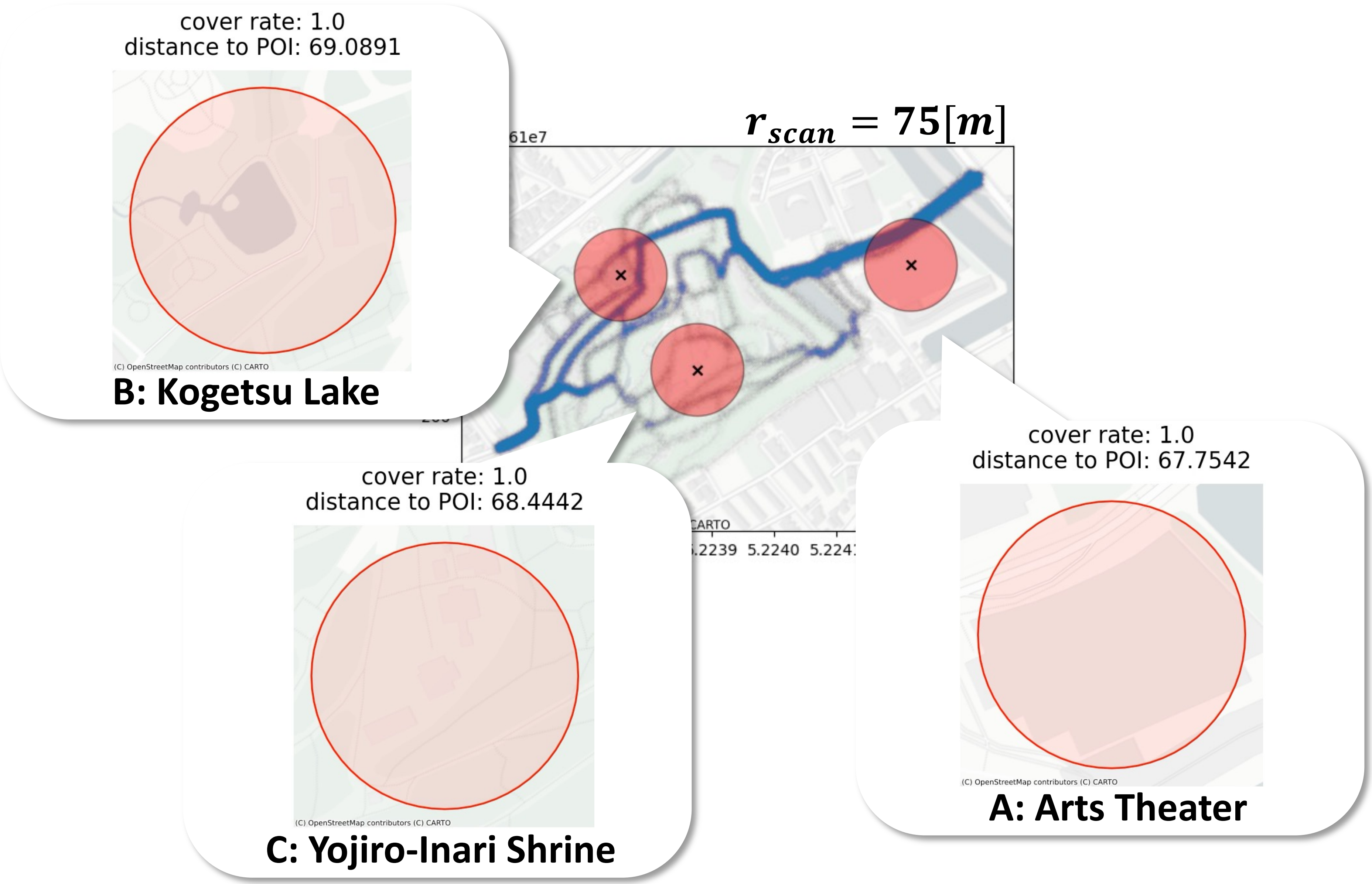
N-times

↓

$\boldsymbol{i_{best} = (x, y, r)}$



Demonstration of our solutions



Key Points before detailed explanations

In POI notifiers, geofences that are set manually cannot be optimized from the two perspectives: distances of notification-to-POI (location relevance) and user coverage rates.

Our solution using a Genetic Algorithm enables us to reset their parameters, which leads to better recommendation experiences for many city walkers.

Genetic Algorithm – a meta heuristic technique

Input data

$D = (Tr_1, Tr_2, \dots, Tr_m)$

$poi = (x_0, y_0, a)$

Hyper parameters

r_{scan}: scanning range

cr_{limit}: user coverage rate

$CircularRangeQuery(D, poi, r_{scan})$

$\downarrow D_{sub}$

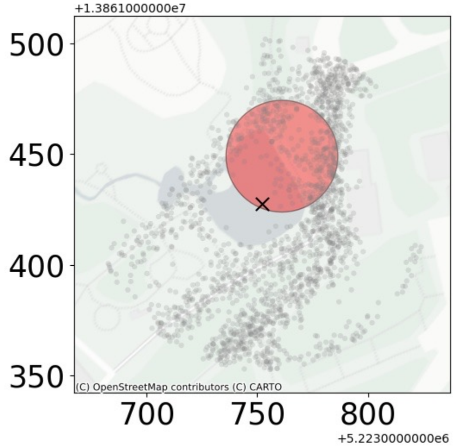
$OptimizeFlexibleCGFWithGA$

- $\underline{CreateIndividual(poi, r_{scan})}$
- $\underline{EvaluateFitness(D_{sub}, poi, cr_{limit})}$
- $Selection()$
- $Crossover()$
- $Mutation()$
- $SelectNextGeneration()$

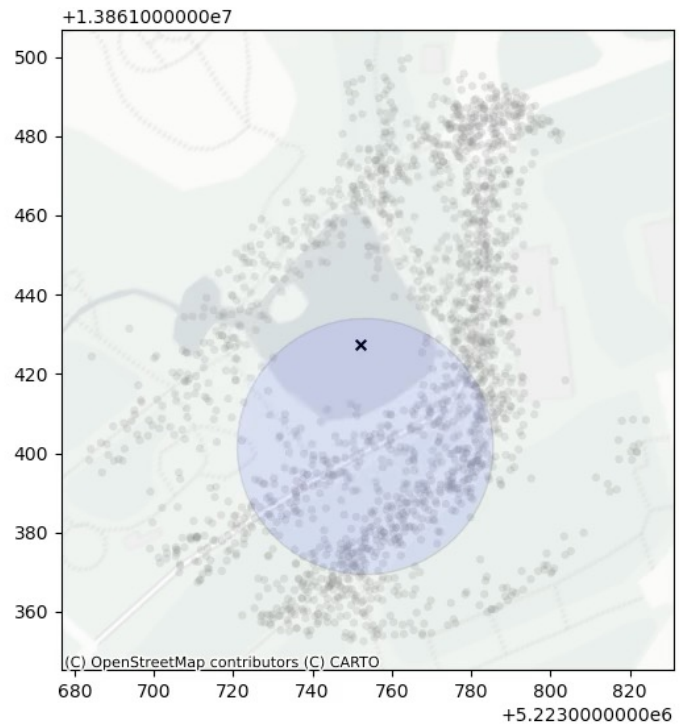
N-times

$\boldsymbol{i_{best} = (x, y, r)}$

i_{best}



Generation 1



Formulation for good POI notifiers

For geofence individual $i = (x, y, r)$,

$$minimize\ F(i) = f(i) + g(i)$$

- location relevance for POI

$$f(i) = \frac{dist(poi.xy, i.xy) + i.r + |dist(poi.xy) - i.r|}{2}$$

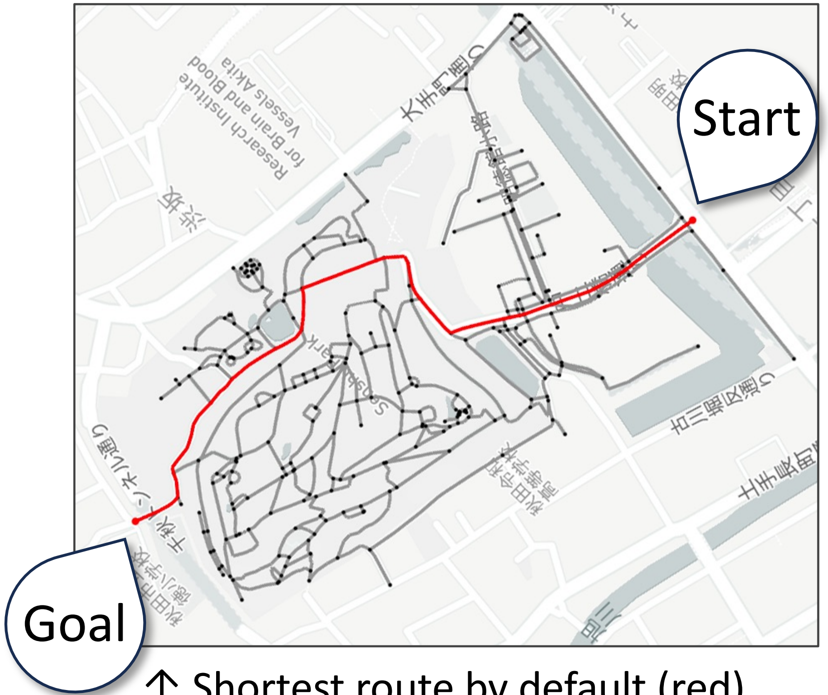
- penalty: user coverage rate

$$g(i) = \mu\ max(0, cr_{limit} - cr(i))$$

μ: *penalty coefficient* (= 2000)
cr_{limit}: *desirable user coverage rate*

Preparation: Synthetic GPS trajectories

Senshu Park (Japan)



↑ Shortest route by default (red)

1. Prepare road networks from OSM:

- Edges are weighted by their lengths [m]

2. Cost scaling:

```
for edge in network.edges:
    edge.weight = random.uniform(
        from edge.weight/2 to edge.weight*2
    )
```

3. Route selection: Dijkstra Algorithm

4. Generate trajectory data

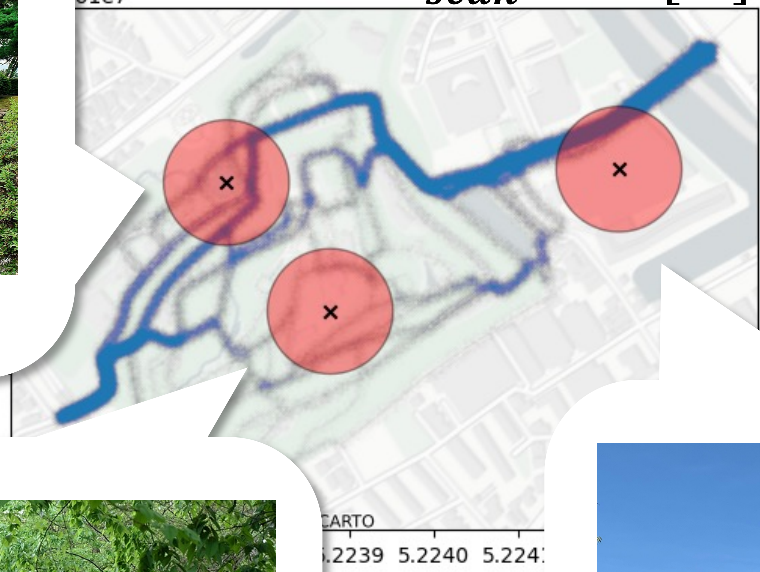
- Recording interval [s]: 8.0
- Walking speed [m/s]:
  $random.normal(\mu = 1.3, \sigma = 0.2)$
- GPS Noise [m]:
  $random.normal(\mu = p_{user}, \sigma = 5.0)$

Preparation: target POIs

Different point patterns within the scanning range r_{scan}.

600 trajectories

$r_{scan} = 75[m]$



B: Kogetsu Lake

by Ippukucho (Wikipedia)

C: Yojiro-Inari Shrine

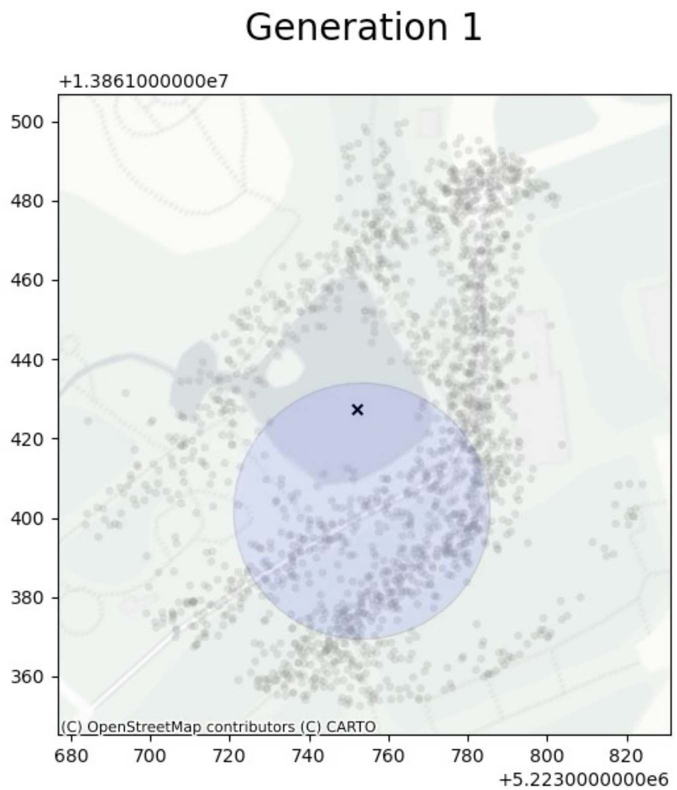
A: Arts Theater

Performance Stability of the Genetic Algorithm

Examining **the variability of solutions** as the user coverage rate cr_{limit} increases.

- **30** trials for each parameter
- **150** trajectories within the scanning range

(A: 150, B: 210, C: 565 trajectories in the dataset)



* In this presentation, the same parameters have been applied for the Genetic Algorithm.

Crossover probability = 0.5

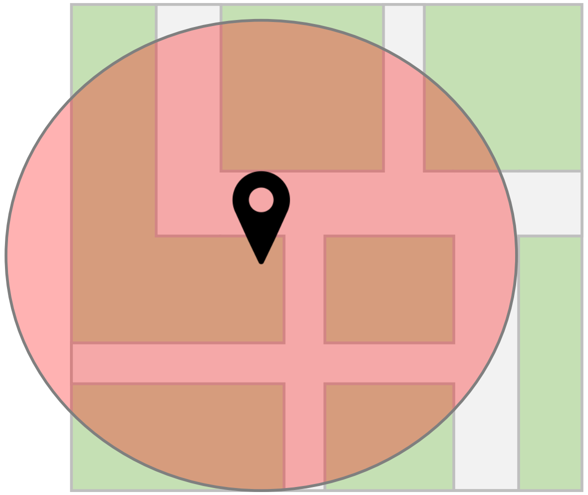
Mutation probability = 0.1

Number of generations = 150

Population size = 300

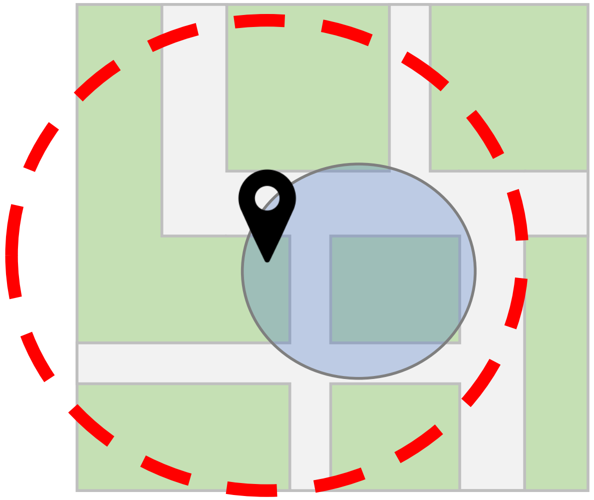
penalty coefficient = 2000

A larger geofence,
which would cover
a more extensive area
$i = (poi.x, poi.y, 75m)$



vs.

Our Solution
scanning range: $r_{scan} = 75m$
desirable user coverage rate:
$cr_{limit} = 1.0$

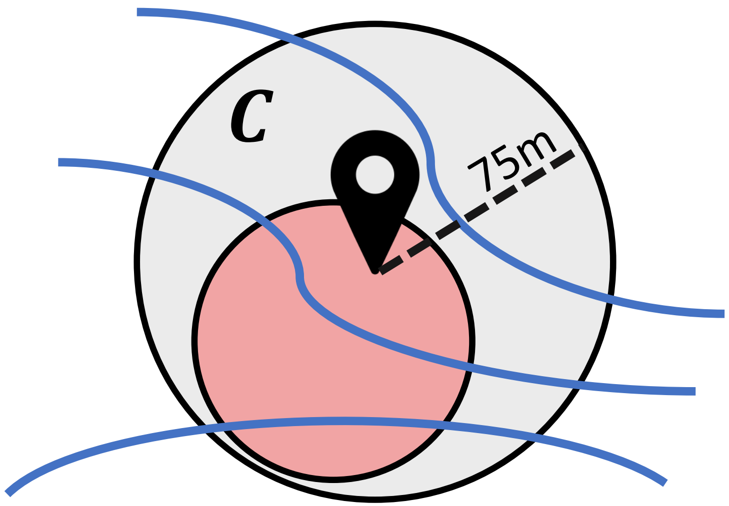


Examining the scalability of the algorithm
as the input data increases.

- For training: 10 – 300 trajectories
- User coverage rate: $cr_{limit} = 1.0$
- **CGF by manual** (Scanning range): $C = (poi.x, poi.y, 75)$

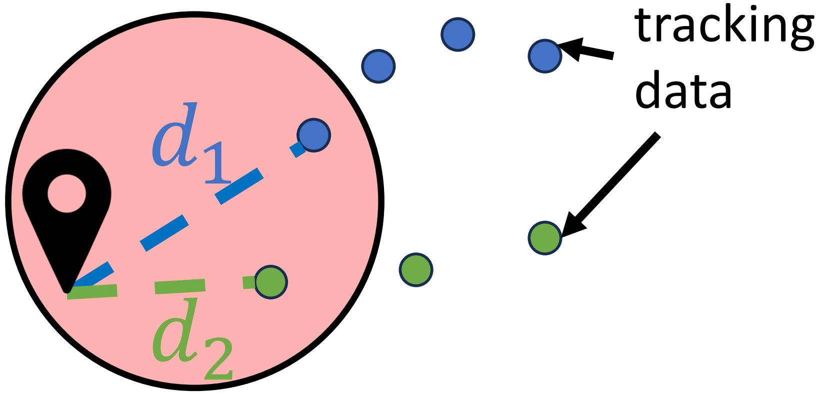
For test: 200 trajectories

(1) User coverage rate



$$= \frac{\boldsymbol{traj\_num(in\colon\ i_{best})}}{\boldsymbol{traj\_num\ (in\colon C)}}$$

(2) Average distance of notification-to-POI



$$= \frac{\sum_{k=1}^{n} \boldsymbol{d_k}}{\boldsymbol{n}}$$

Results

- The simpler the point pattern, the more stable it is.
- As the user coverage rate increases,
  the output becomes slightly more unstable.

- Increasing the training data size contributes to the improvement of the user coverage rate.
- The more complex point patterns the scanning range has, (2) becomes sensitive to changes in the number of training data.

Summary

The accumulation of tourists' GPS trajectory data can empower us to find better geofence parameters than manually settings from the two perspectives: the user coverage rate and location relevance.

(GPS logs know the tendency of tourists' flow and the technical limitations better than humans...?)

Geofencing is widely used in the tourism business. The strategy of geofence design depends on the purpose and domain of the service. In the future, further discussion on systematizing autonomous optimizations in geofencing technology (not only for POI notifiers) are needed.