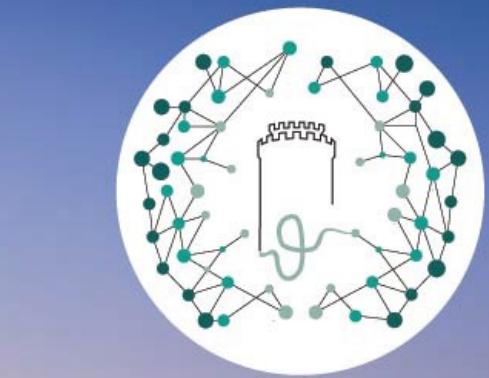


# Proposal of mathematical model of prediction of human movement on sightseeing using position information

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THESSALONIKI  
GREECE  
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# Purpose

- Construct a mathematical model describing and predicting the behavior of tourists. The theory is based on stochastic processes.
- We narrow down the target to foreign tourists whose importance is increasing in the future, and obtain and analyze the behavior data with NEC's cooperation.
- In this report, in the case of Shizuoka where the number of sightseeing spots is small and the number of tourists visited is small, the mathematical model is constructed and actual data is analyzed. We will link the results to the analysis of data in Tokyo and Kyoto.

# DataSet of foreign sightseeing visitors in Japan (NEC)

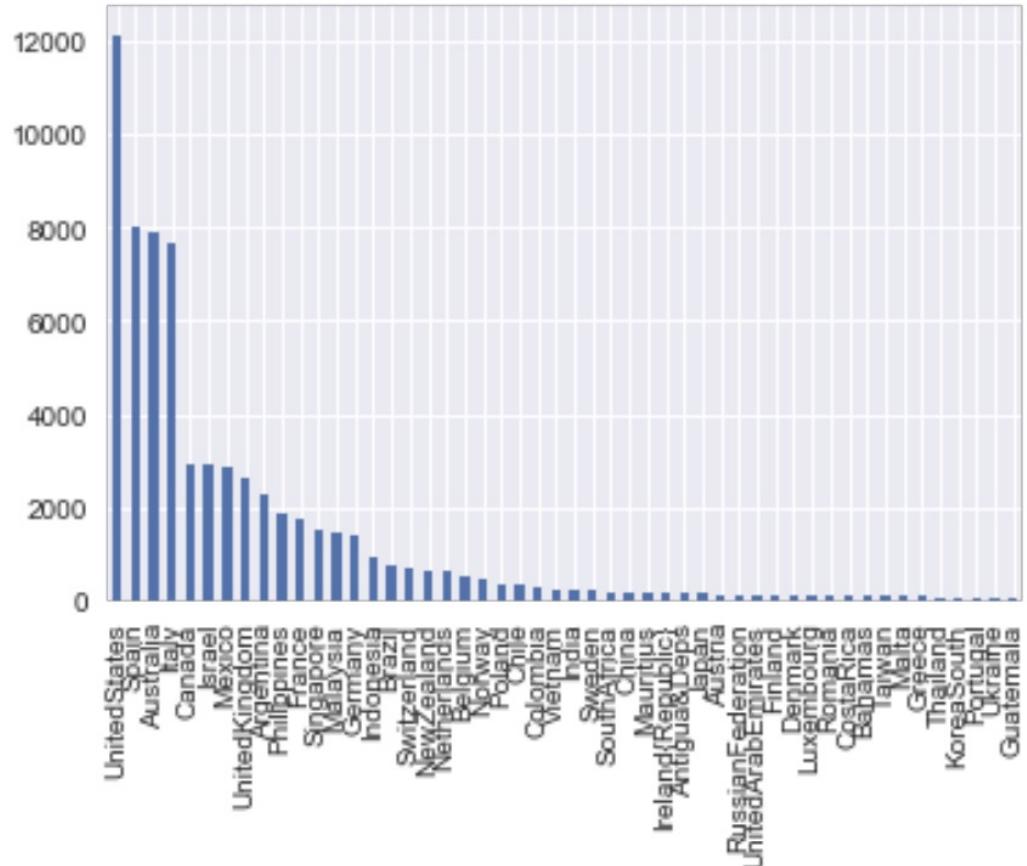
- Regions
  - Shizuoka prefecture.....4 cities
  - Tokyo prefecture .....38 cities
  - Kyoto prefecture
- We use Shizuoka data
- The behavior of the group of foreign tourists is recorded in detail by the travel guide. A lot of information such as the place visited, the staying time, the contents of sightseeing, the weather, the temperature, the meal contents, the contents of shopping, the expenditure amount, etc. are recorded.

Yasuko Kawahata, Yukari Moriyama, Shinichirou Yamada, Mingyi Sun, and Taketo Kawamura.

"Analytical the Large-scale Collection of Data on the Results of the Guides for Foreigners Visiting Japan".

2017 IEEE International Conference on Big Data(BIGDATA) (2017)

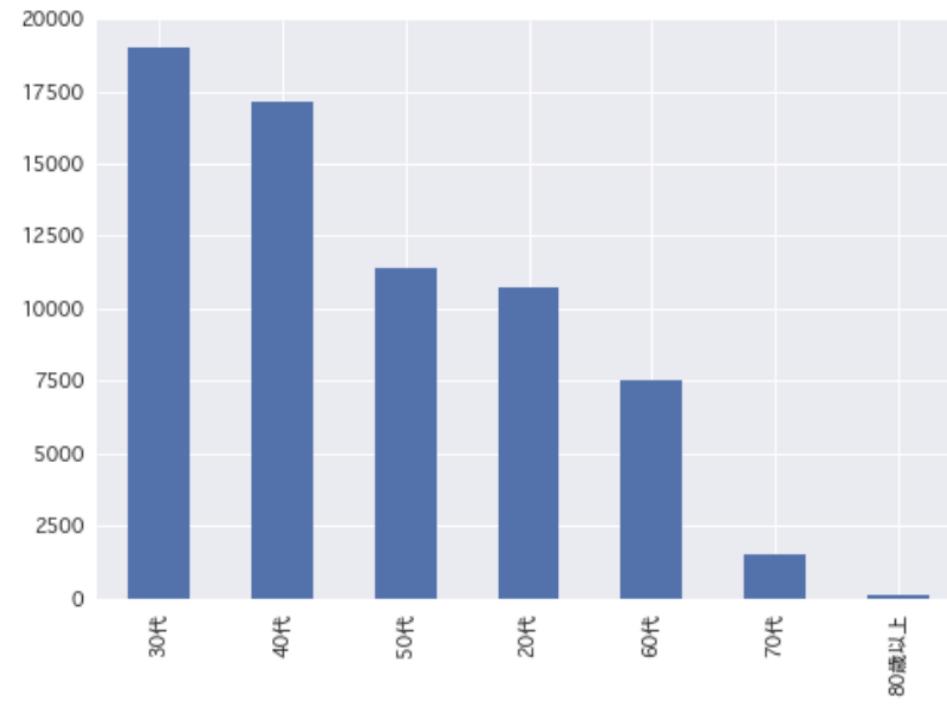
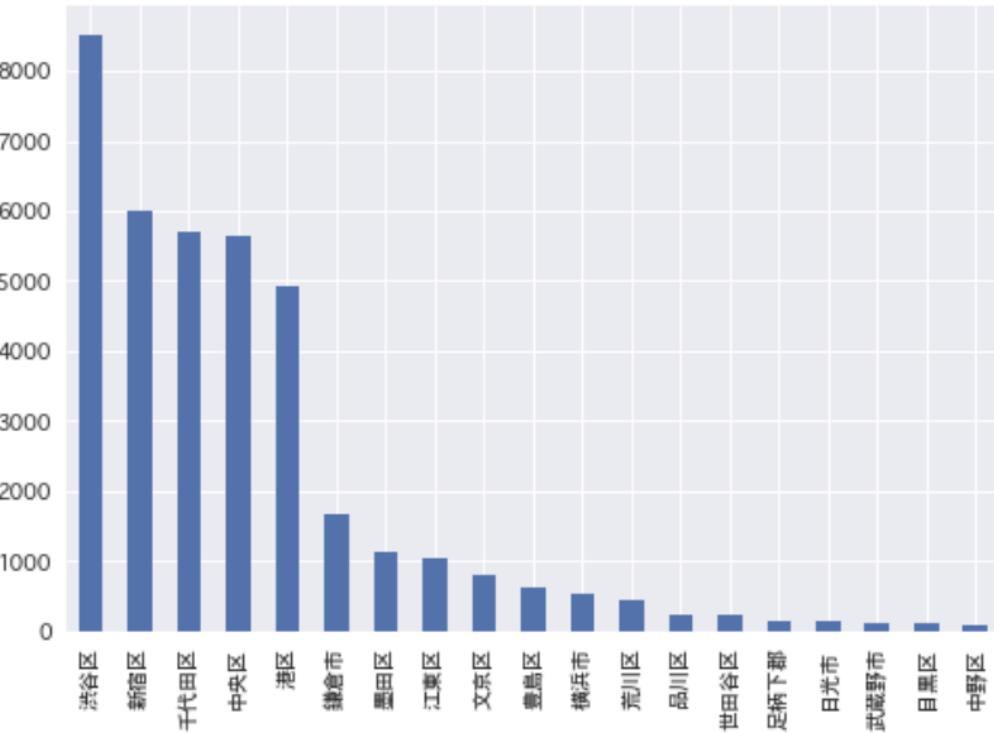
# About DataSet of foreign sightseeing visitors in Japan



Here are very many people who have used guides in the Tokyo Metropolitan Area from the United States of America, and this is followed by people from Spain, Australia, Italy, Canada and Israel. Looking at the nationalities and regions in the recent studies on the spending trends of visitors to Japan.

Number of groups divided according to nationality who used a guide of the Tokyo suburbs activity

# About DataSet of foreign sightseeing visitors in Japan



Spots where purchases were made by groups who used a guide of the Tokyo area activity

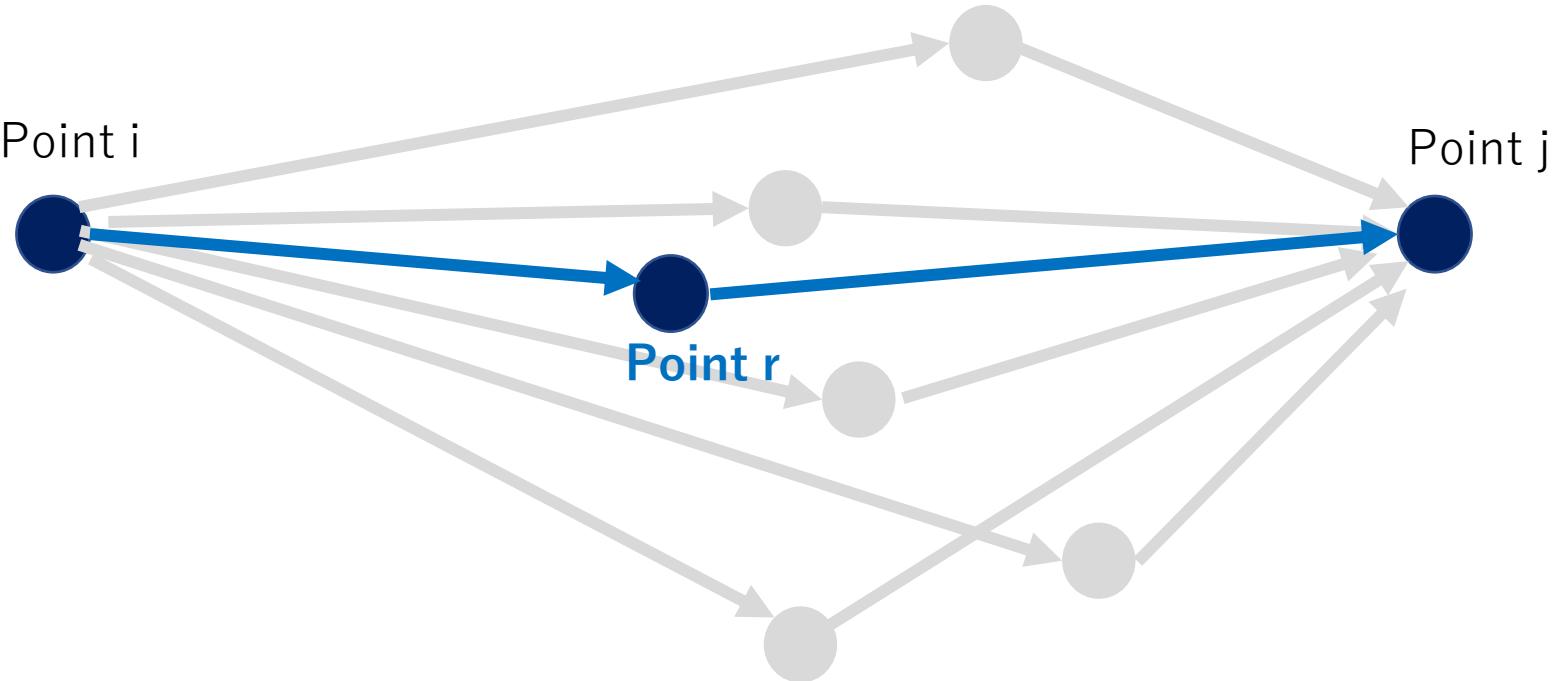
Point i

Point j



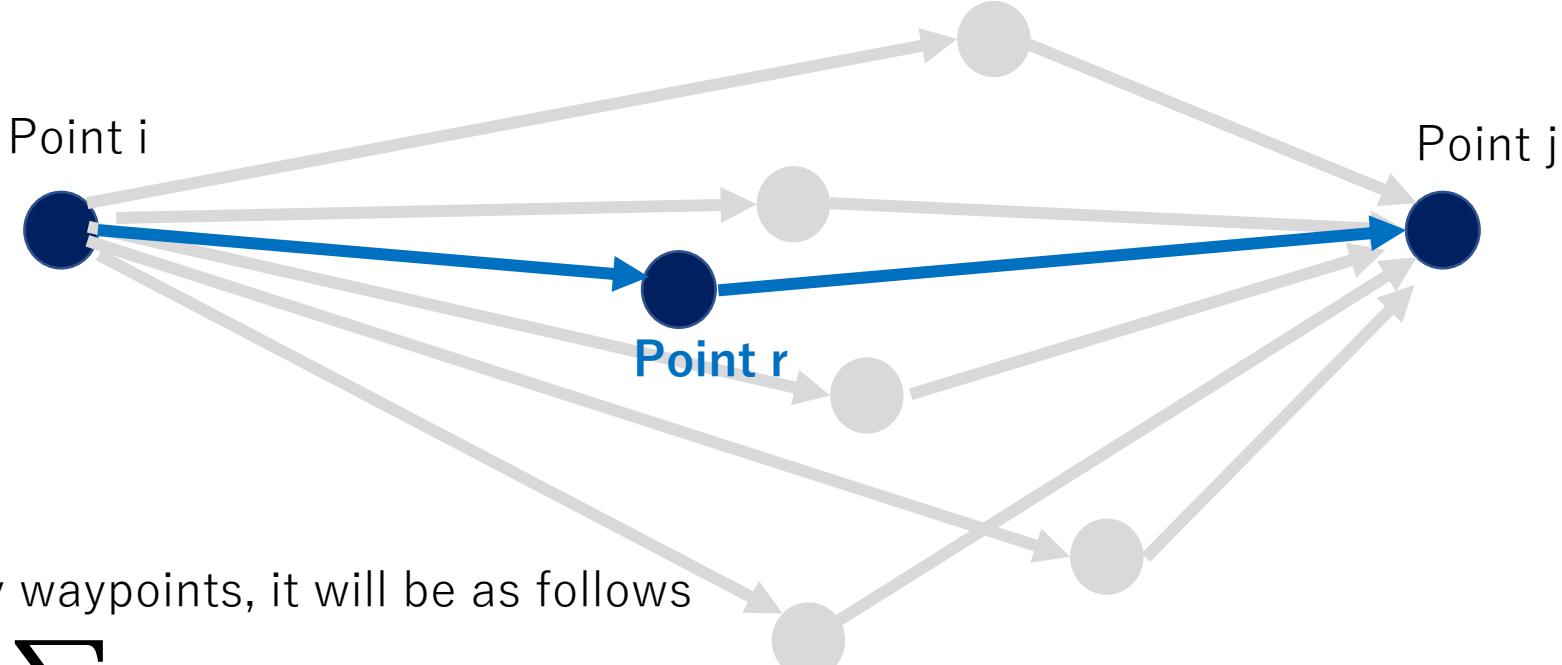
$P_{ij}$  Probability to go from point i to j

$P_{ij}(t, t_0)$  The probability of departing  
from point i at time  $t_0$   
and going to point j at time t



On the way, if you visit to point *r* before *j*

$$P_{ij} = P_{ir} P_{rj}$$



If there are many waypoints, it will be as follows

$$P_{ij}(t, t_0) = \sum_r P_{ir}(t_r, t_i) P_{rj}(t, t_r)$$

Furthermore, taking into account the time spent on the waypoint

$$P_{ij}(t, t_0) = \sum_r P_{ir}(t_1, t_i) \underline{Q_r(t_2, t_1)} P_{rj}(t, t_2)$$

**Stay at point r from time  $t_1$  to  $t_2$**   
**This function Q corresponds to the collection of information  
on how tourists spend at each tourist spot**

Distribution function of how long it takes to go from i to j

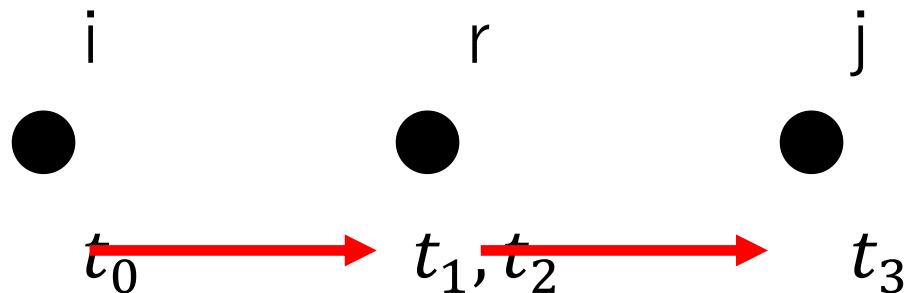
$$f(t) = P_{ij}(t, t_0) = \sum_r P_{ir}(t_r, t_i) P_{rj}(t, t_r)$$

Distribution function of how long to stay at r point

$$\underline{Q_r(t_2, t_1)}$$

$$P_{ij}(t, t_0) = \sum_r P_{ir}(t_1, t_i) \underline{Q_r(t_2, t_1)} P_{rj}(t, t_2)$$

# Simplified model with 3 points only



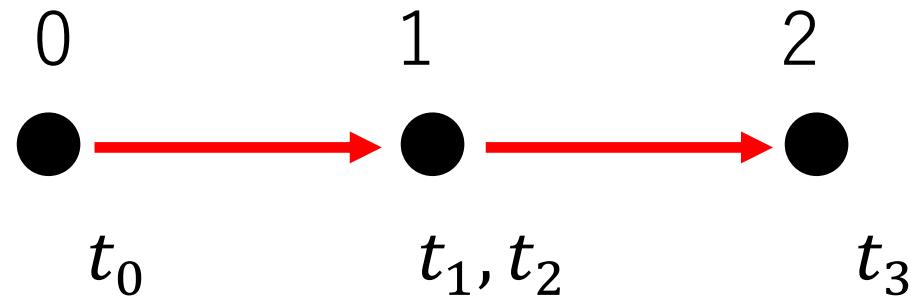
- Consider the case where the position  $i$  is at time  $t_0$ , the position  $r$  is from time  $t_1$  to  $t_2$ , and the position  $j$  is at time  $t_3$
- $I(t)$  is the position where a person is at time  $t$

$$I(t_0) = i,$$

$$I(t_1) = I(t_2) = r,$$

$$I(t_3) = j$$

# Simplified model with 3 points only



- Let positions  $i, r, j$  be  $i = 0, r = 1, j = 2$  respectively
- $I(t)$  can be expressed as follows
$$I(t_0|i) = 0, I(t_1|r) = I(t_2|r) = 1, I(t_3|j) = 2$$
- We do not think the actual distance between cities here

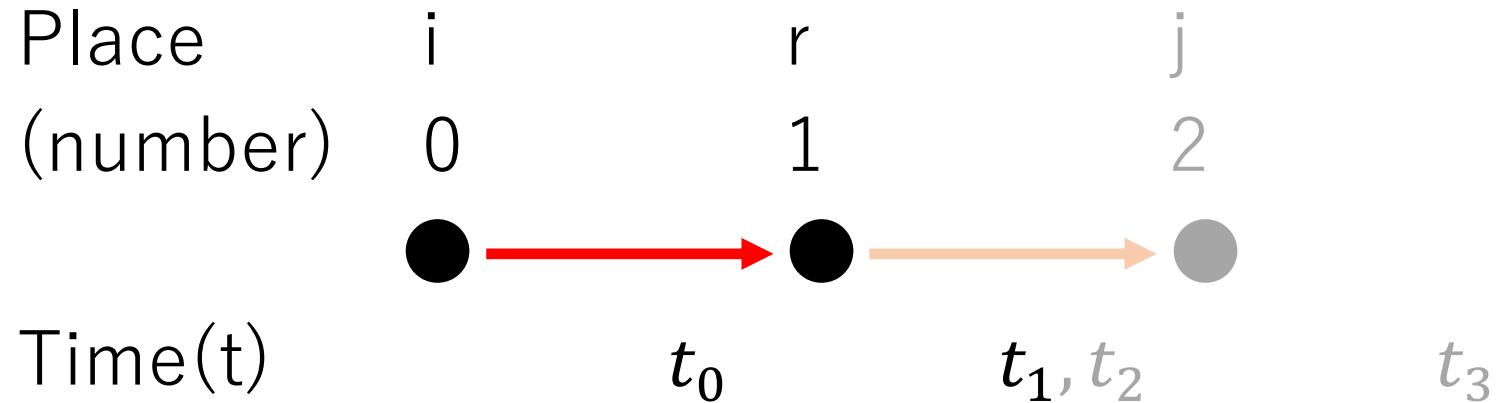
# Simplified model with 3 points only

- Position of a person

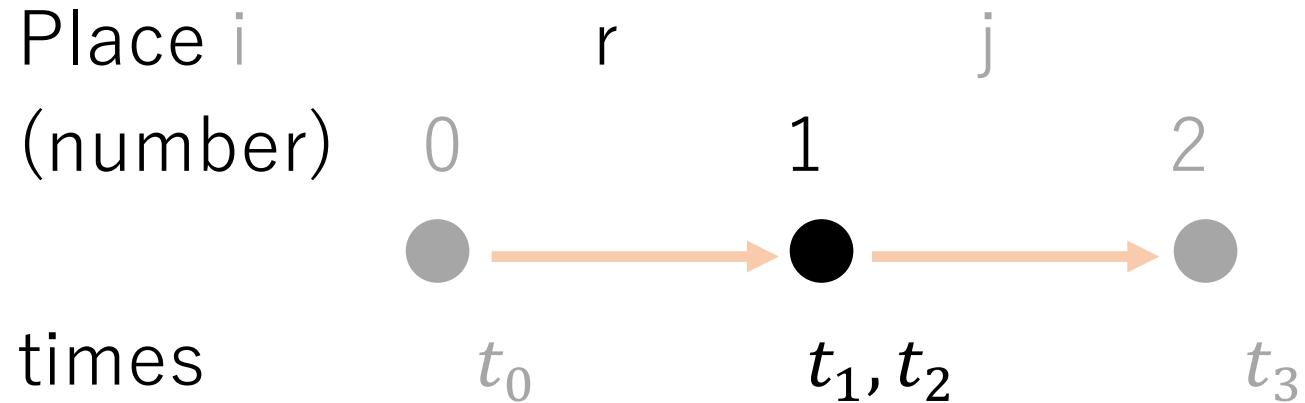
$$I(t_n|\beta) = I(t_{n-1}|\alpha) + \underbrace{M(\alpha, \beta)}_{\text{People's movement}} \underbrace{P_{\alpha\beta}(t_{n-1}, t_n)}_{\text{Transitive probability matrix}}$$

$$M = \begin{cases} \beta - \alpha & (\alpha < \beta) \\ 0 & (\alpha = \beta) \\ \alpha - \beta & (\alpha > \beta) \end{cases}$$

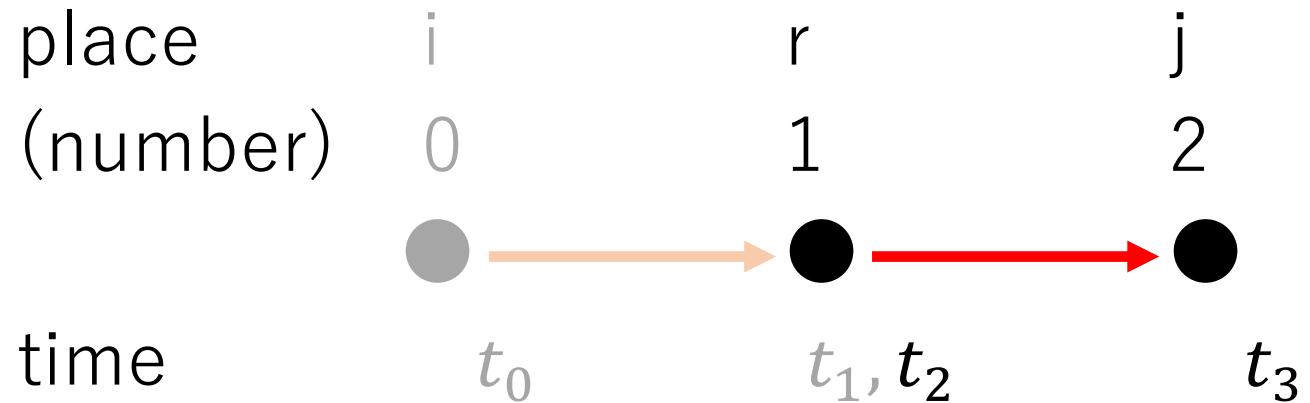
Here, proceeding from  $\alpha$  to  $\beta$



$$\begin{aligned}
 I(t_1|r) &= I(t_0|i) + M(i,r) \\
 &= 0 + 1 \\
 &= 1
 \end{aligned}$$

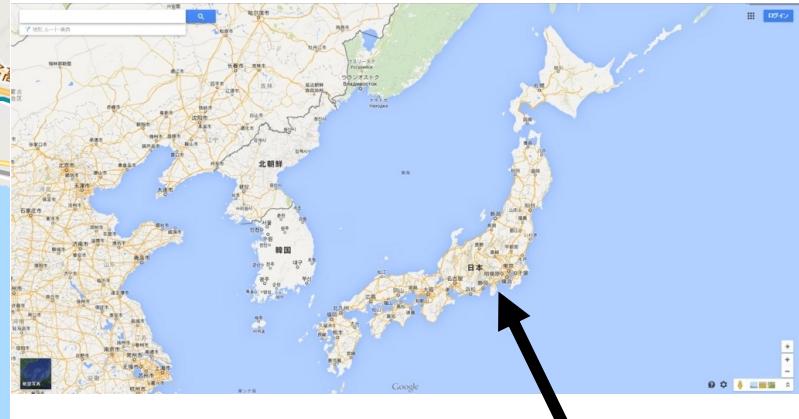
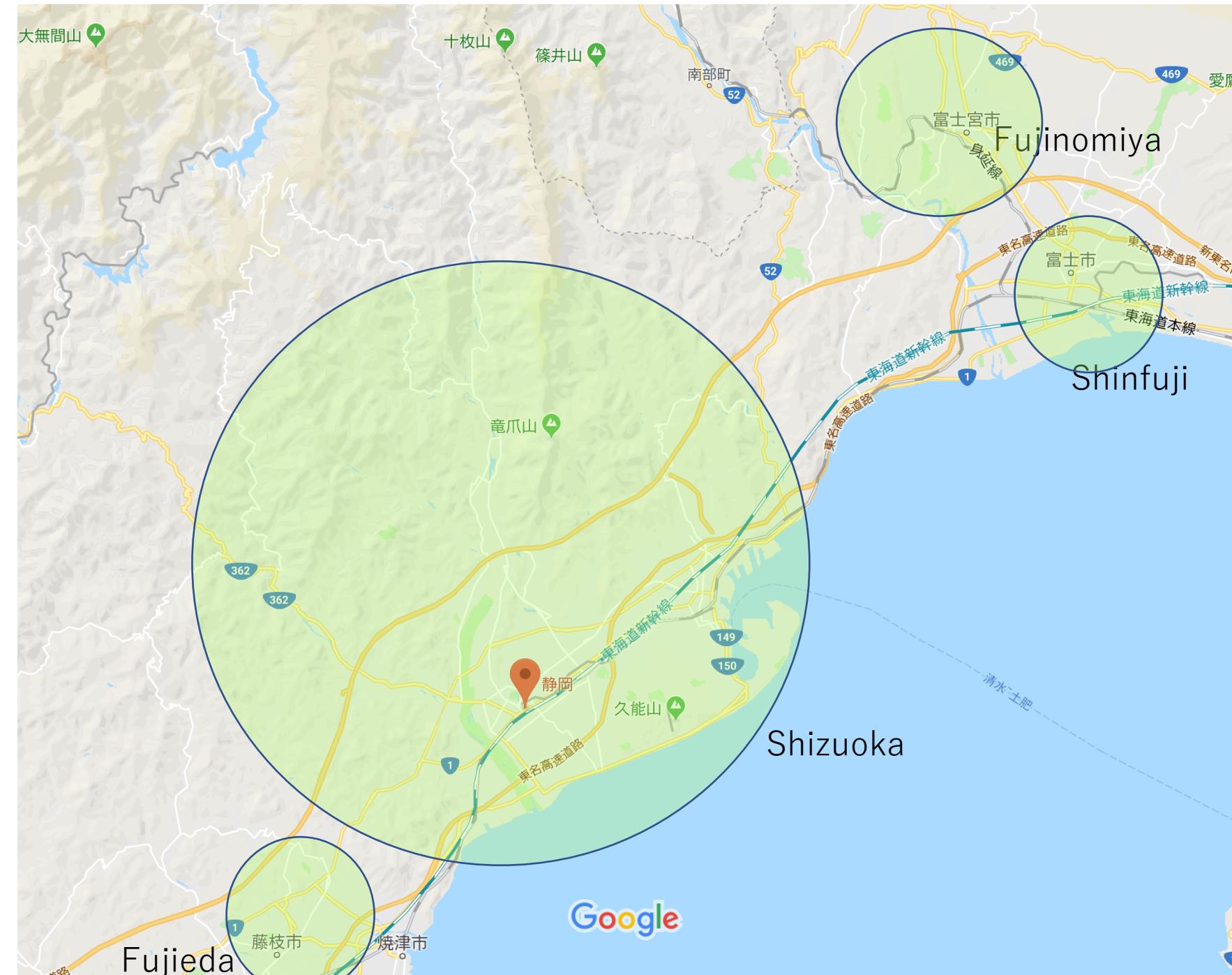


$$\begin{aligned}
 I(t_2|r) &= I(t_1|r) + M(r,r) \\
 &= 1 + 0 \\
 &= 1
 \end{aligned}$$



$$\begin{aligned}
 I(t_3|j) &= I(t_2|r) + M(r,j) \\
 &= 1 + 1 \\
 &= 2
 \end{aligned}$$

# Location of clusters



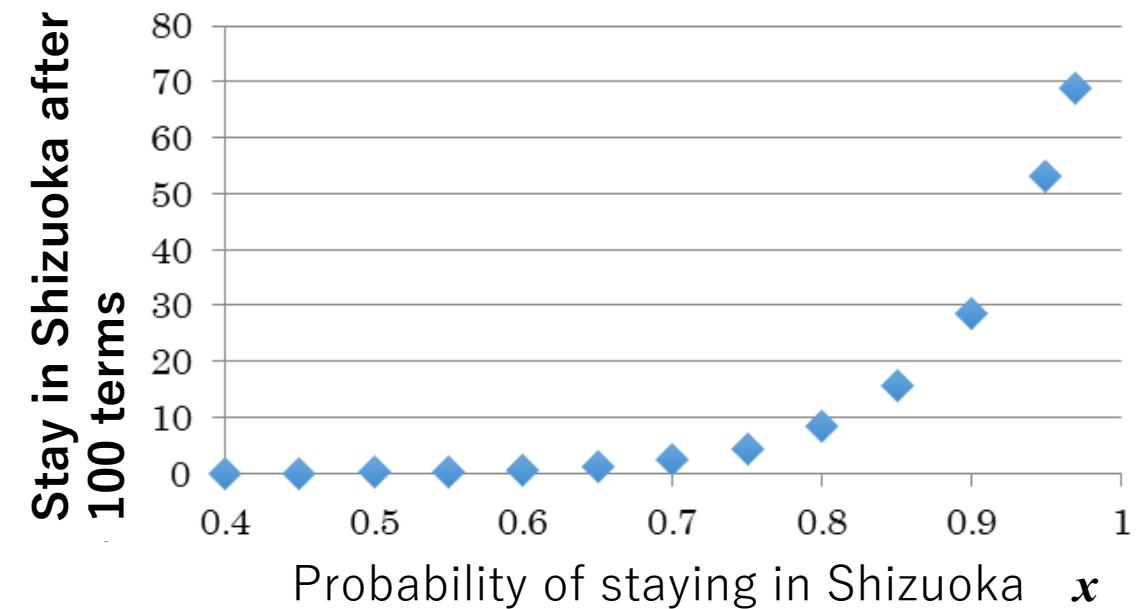
Shizuoka

# Transition Probability Matrix for German on this 4 area

	Shizuoka	Shinfuji	Fujinomiya	Fujieda
Shizuoka	0.971	0	0.029	0
Shinfuji	0.500	0.500	0	0
Fujinomiya	0	0.333	0.667	0
Fujieda	0	0	0	0

- The probability of staying in Shizuoka city is very high

移動前/移動後	Shiuoka	Shinfuji	Fujinomiya	Fujieda
Shizuoka	$x$	0	$1 - x$	0
Shinfuji	0.500	0.500	0	0
Fujinomiya	0	0.333	0.667	0
Fujieda	0	0	0	0



- The average percentage that does not move at all from Shizuoka city exponentially increases.

# Sightseeing spots in Shizuoka Prefectures

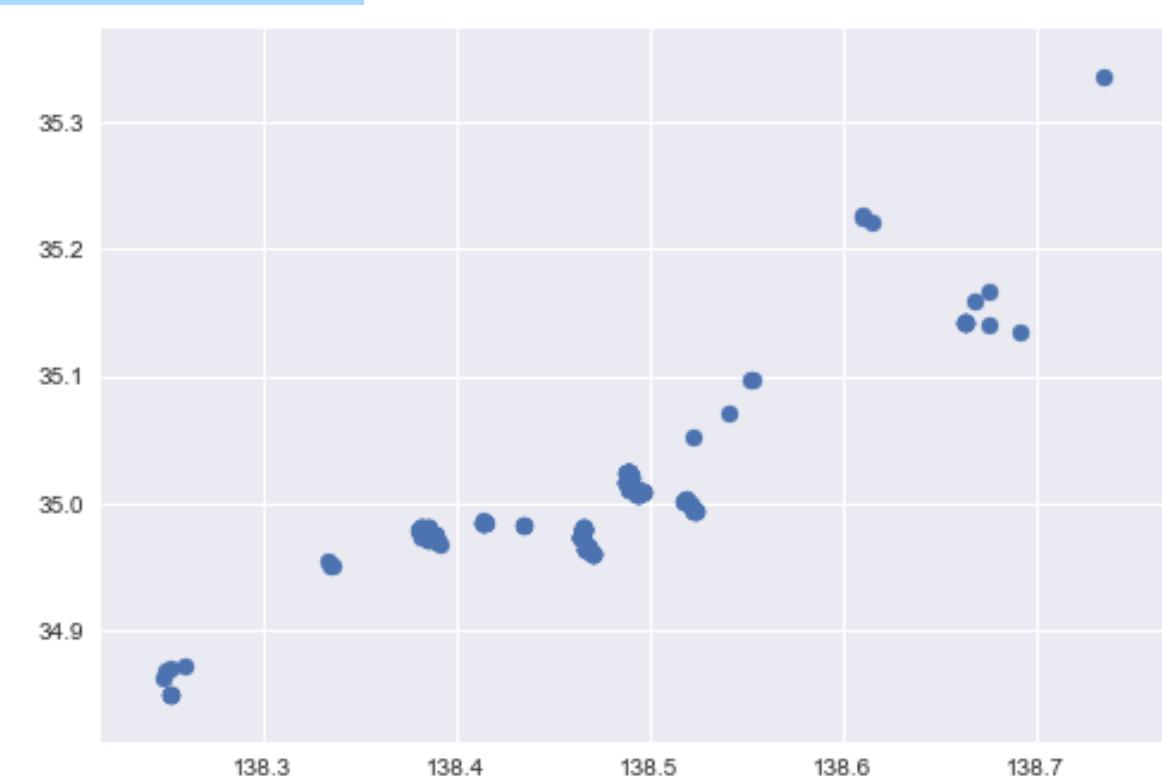
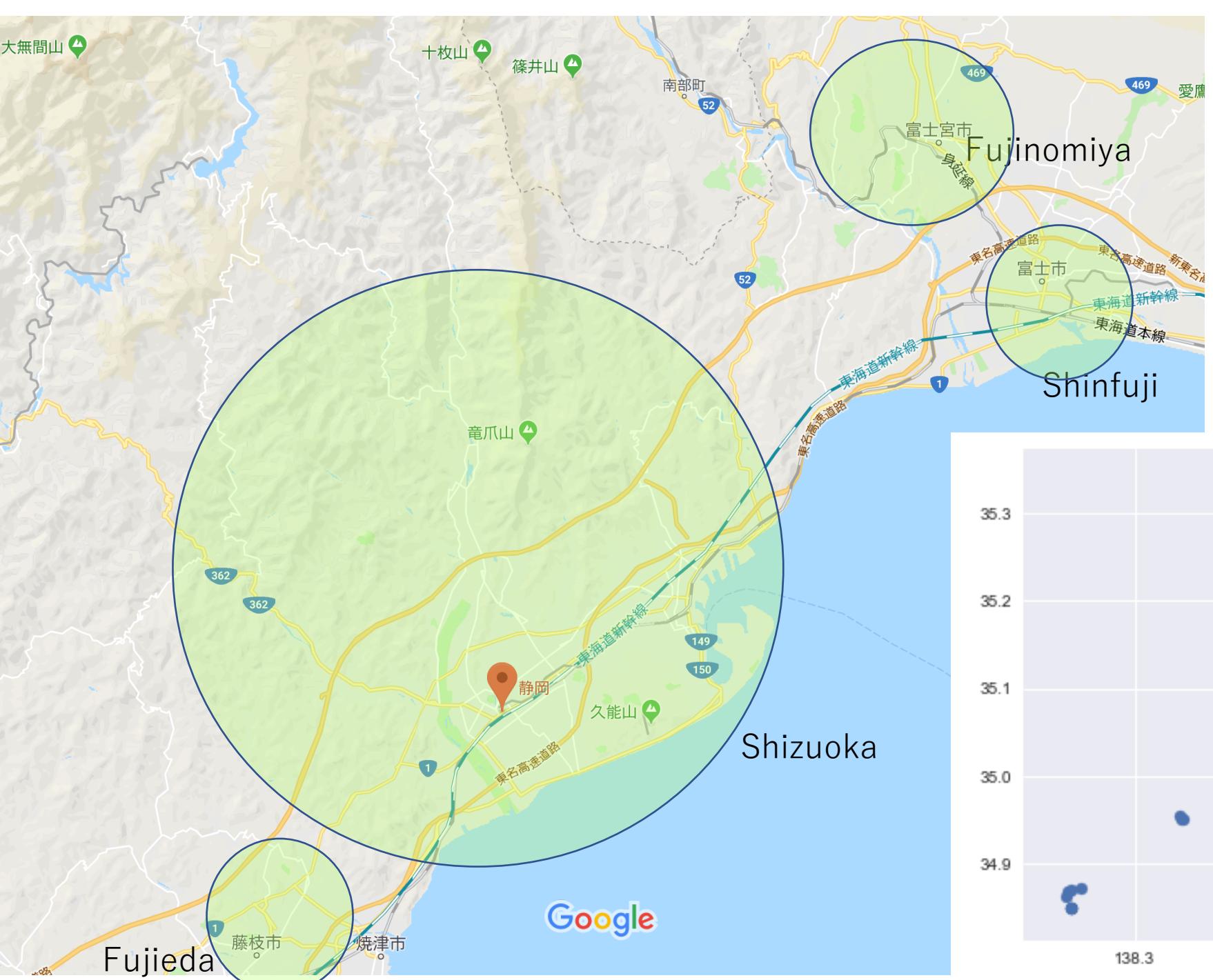
[ '静岡街中' ,  
'清水港' ,  
'清水港周辺' ,  
'丸子' ,  
'静岡駅周辺' ,  
'日本平・久能' ,  
'吳服町・両替町・紺屋町' ,  
'富士市' ,  
'静岡駅' ,  
'駿府城公園内' ,  
'久能山下' ,  
'ドリームプラザ' ,  
'藤枝市内' ,  
'富士山本宮浅間大社周辺' ,  
'新静岡駅周辺' ,  
'日本平' ,  
'清水駅周辺' ,  
'清水東部' ,  
'藤枝駅周辺' ,  
'三保' ,  
'新富士駅' ,  
'富士宮駅' ,  
'ドリームプラザ' ,  
'～' ,

[ '新清水～' ,  
'新静岡～' ,  
'清水駅～' ,  
'エスパルスドリームプラザ' ,  
'清水駅' ,  
'ドリームプラザ～清水駅' ,  
'清水駅～静岡駅' ,  
'静岡駅南口～日本平ホテル' ,  
'日本平ホテル～清水駅' ,  
'新清水(静鉄)' ,  
'清水駅前(バス)' ,  
'フェルケール博物館' ,  
'久能山東照宮' ,  
'三保松原' ,  
'東静岡駅' ,  
'日本平ホテル' ,  
'日本平駅(ロープウェイ)' ,  
'久能山' ,  
'三保の松原' ,  
'静岡駅前(バス)' ,  
'丸子橋入り口' ,  
'久能' ,  
'静岡駅南口(バス)' ,  
'日本平ホテル(バス)' ,

# Sightseeing spots in Shizuoka Prefectures

'日本平ロープウェイ',  
'マリンターミナル',  
'羽衣の松',  
'駿府城公園',  
'新静岡駅',  
'静岡駅南口',  
'波戸場フェルケール博物館',  
'清水マリンターミナル',  
'波止場フェルケール博物館',  
'江尻(水上バス)',  
'動物園入口',  
'河岸の市',  
'新静岡',  
'万世町(バス)',  
'三保(水上バス)',  
'新清水',  
'東静岡駅北口(バス)',  
'日本平ロープウェイ(バス)',  
'御穂神社',  
'セノバ',  
'ホテル',  
'東静岡駅南口',  
'由比駅',

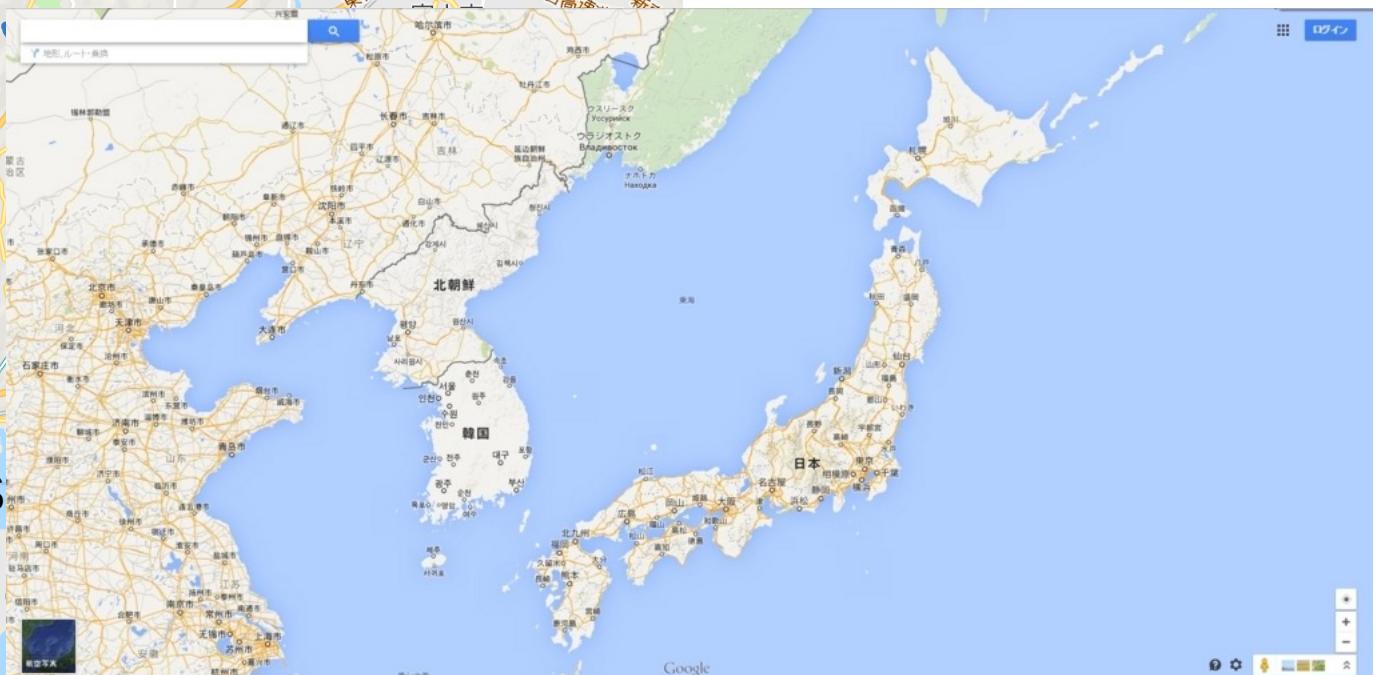
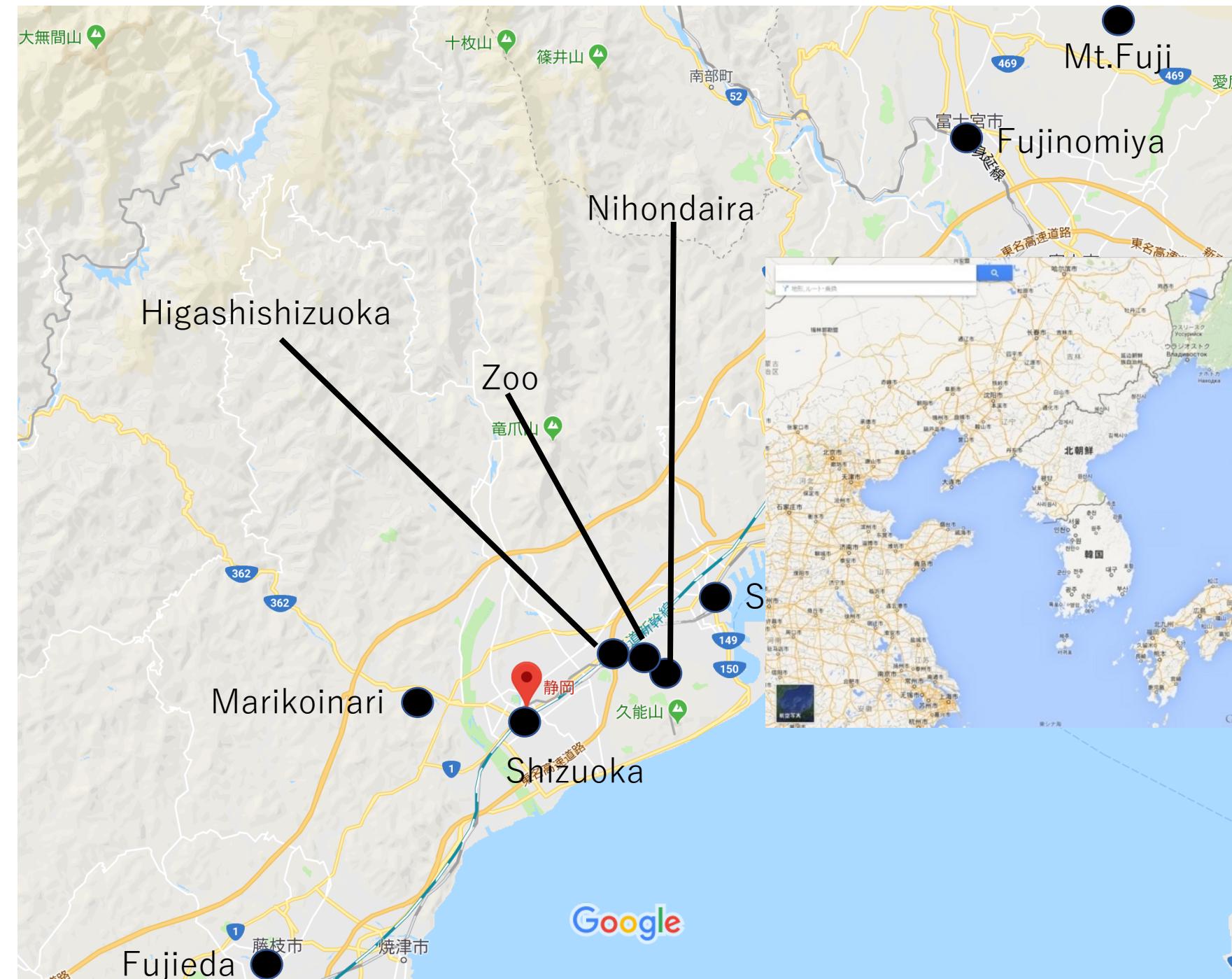
'ロゼシアター',  
'三日市浅間神社',  
'田子の浦港公園',  
'富士山富士宮口五合目',  
'紅葉山庭園',  
'三保ふれあい広場',  
'上伝馬(バス)',  
'藤枝駅前(バス)',  
'フェルケール博物館入口バス停',  
'桑山先生宅',  
'駿河区小鹿',  
'静岡市',  
'富士宮市',  
'駿府城公園周辺',  
'静岡駅新幹線改札',  
'東静岡駅周辺',  
'その他清水区',  
'静岡駅南',  
'富士山',  
'藤枝市')



# Clustering to 11 regions

- Shizuoka (JR station)
- Shinfuji (JR station)
- Fujinomiya (JR Station)
- Shimizu (JR station)
- Nihondaira, Kunousan
- Higashishizuoka (JR station)
- Mihonomatubara
- Marikoinari
- Zoo
- Mt.Fuji
- Fujieda (JR station)
- Others

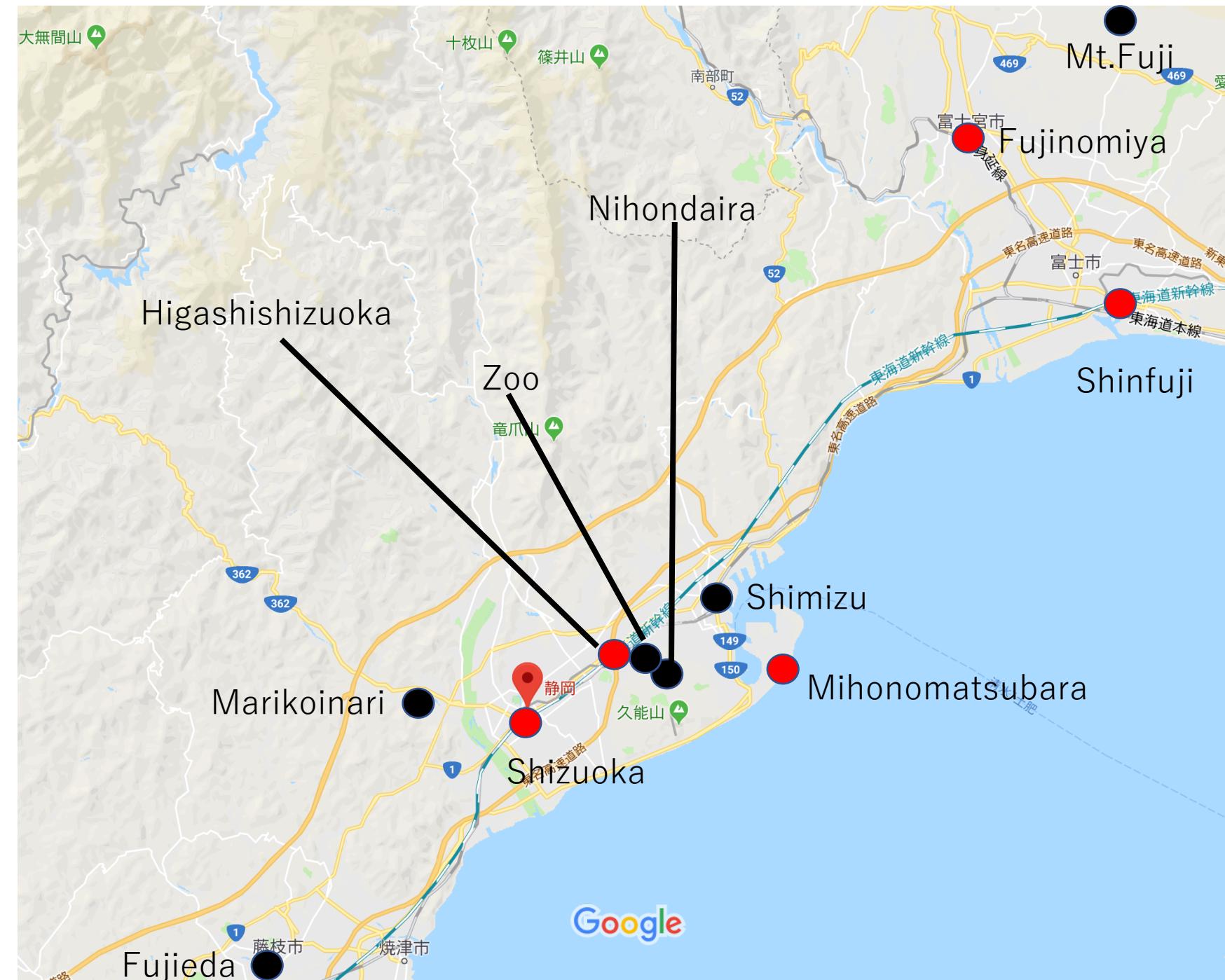
# Location of clusters



# Number of groups in each nationalities

- Germany : 3
- Australia : 7
- United Kingdom : 2
- United States of America : 6
- Vietnam
- Poland
- Portugal
- Malaysia

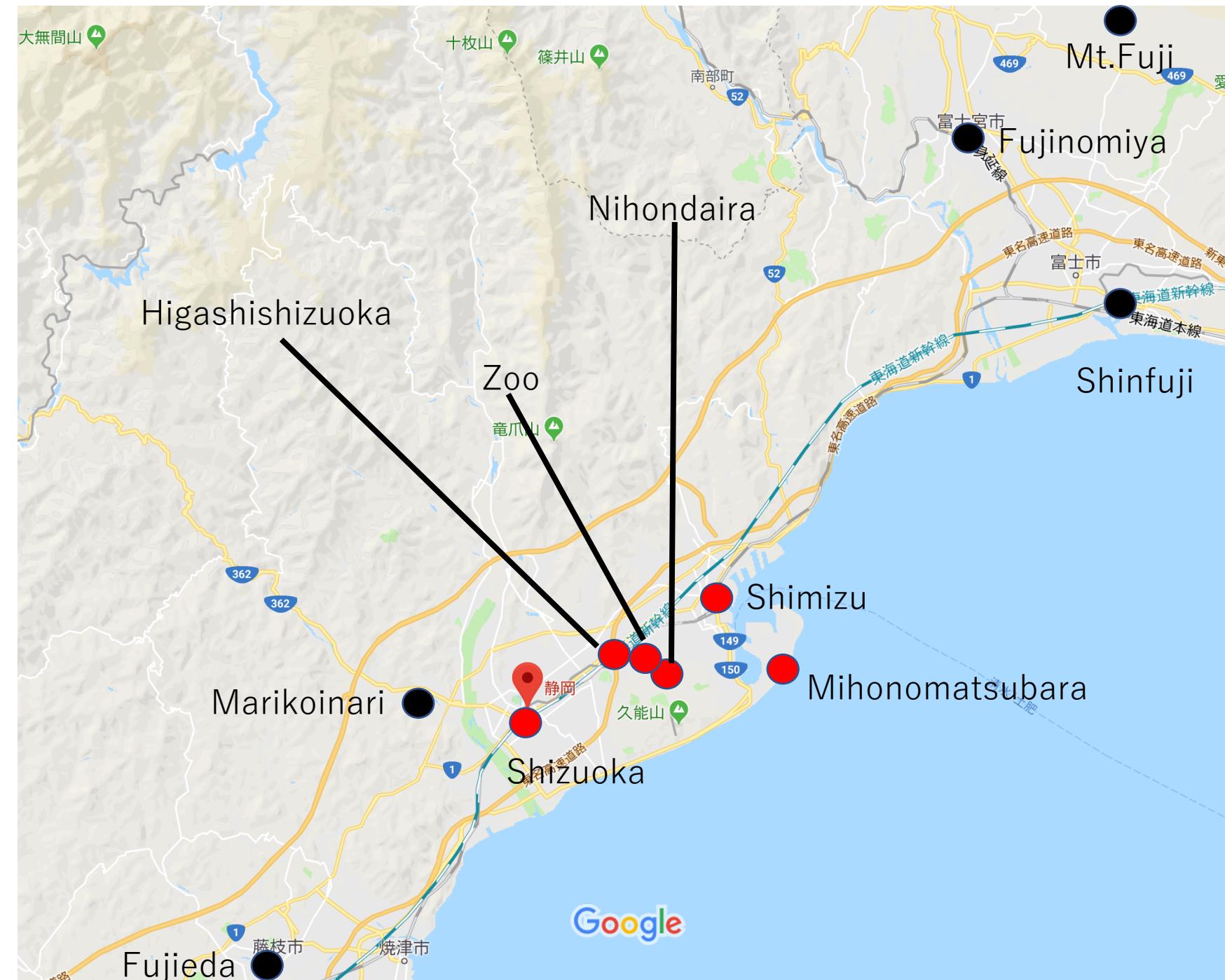
Germany



Google

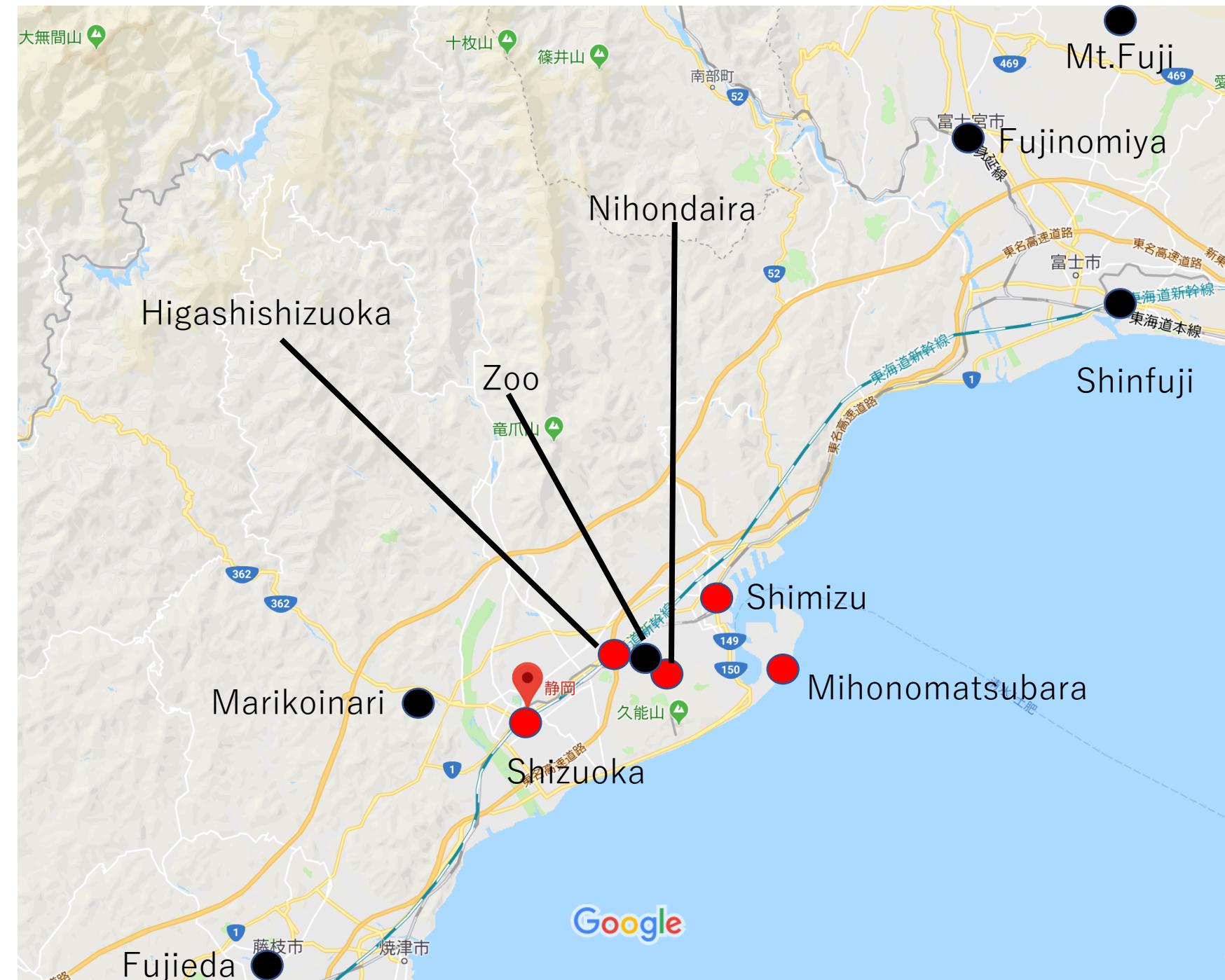
# Germany

Australia



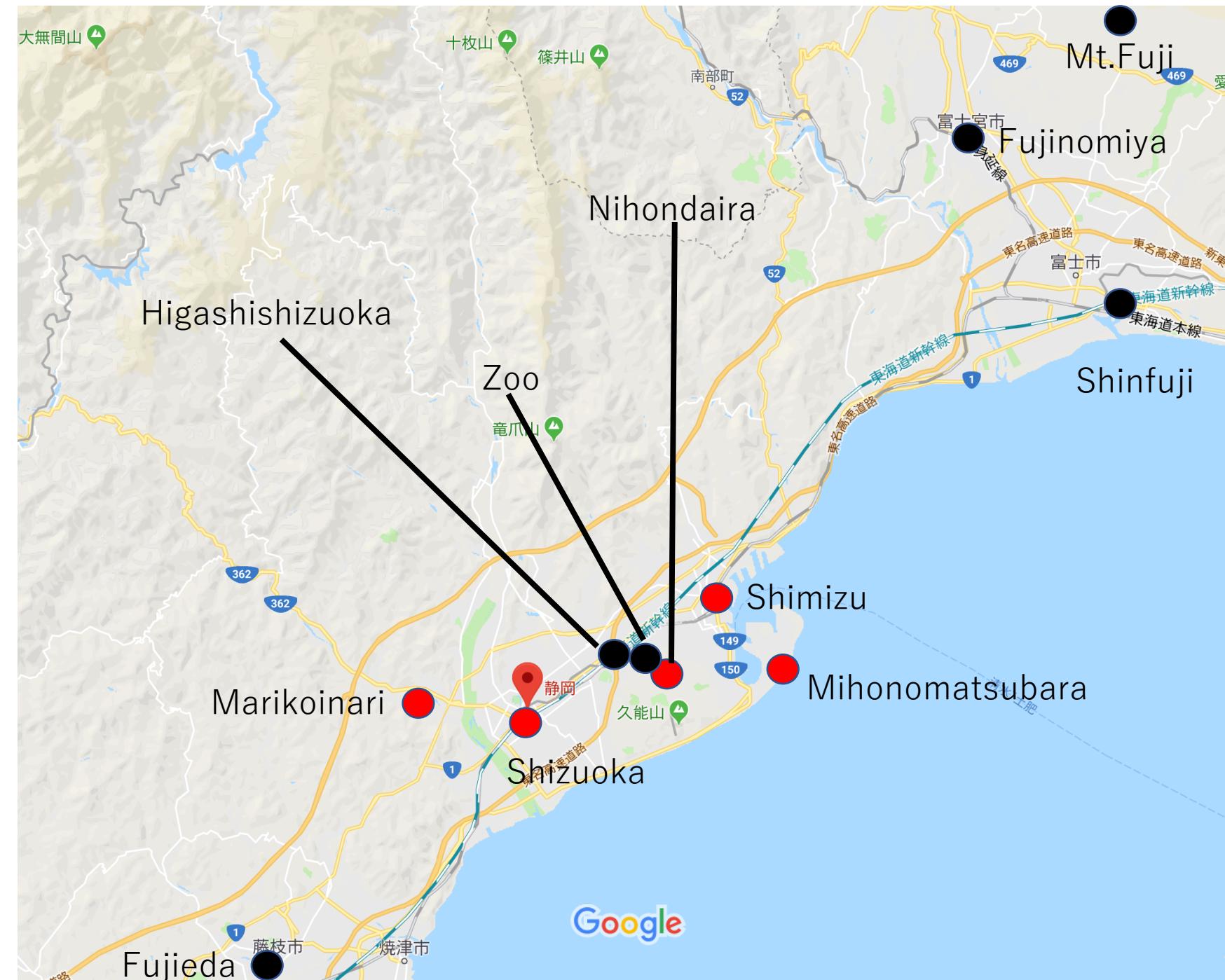
# Australia

United Kingdom



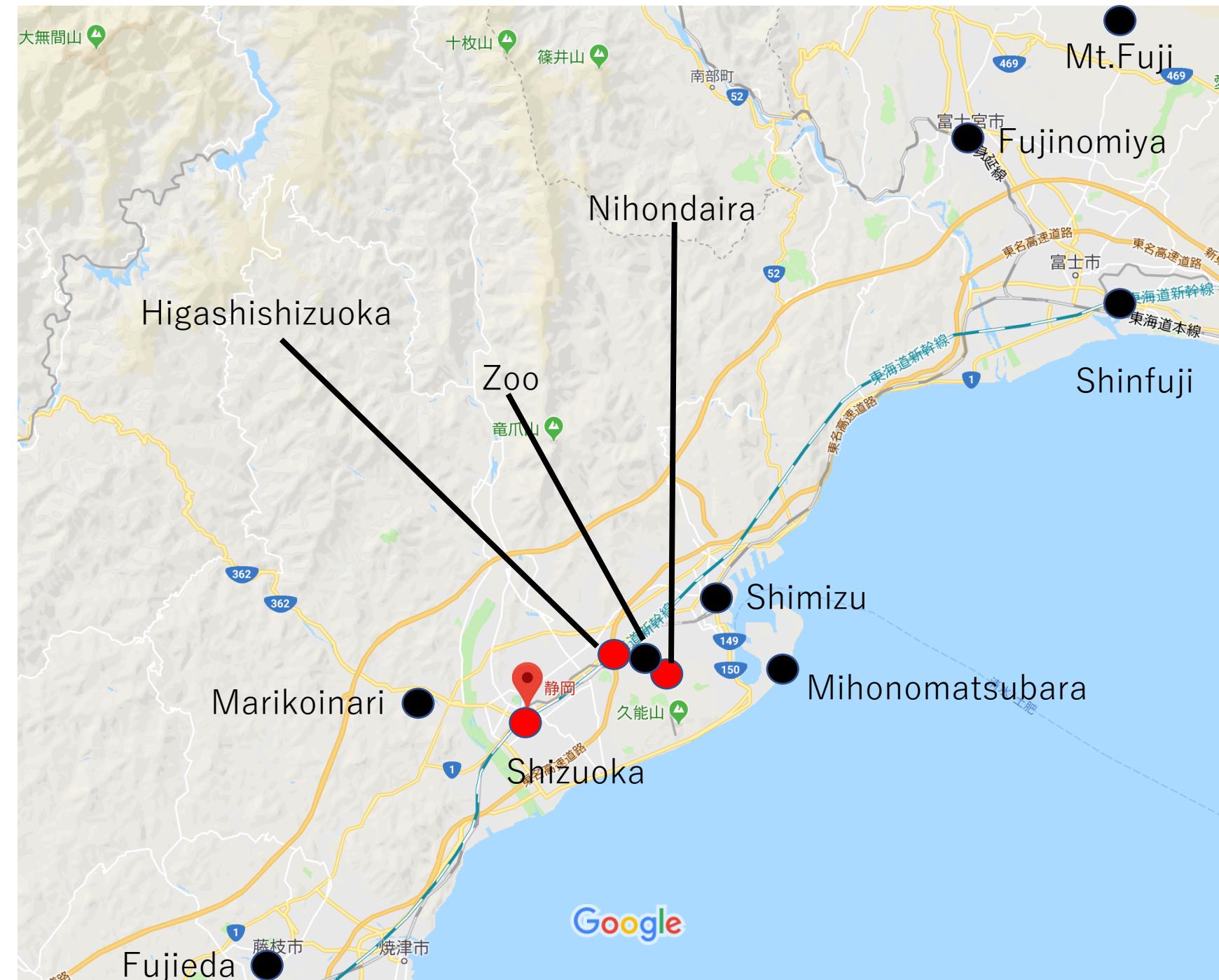
UK

USA



USA

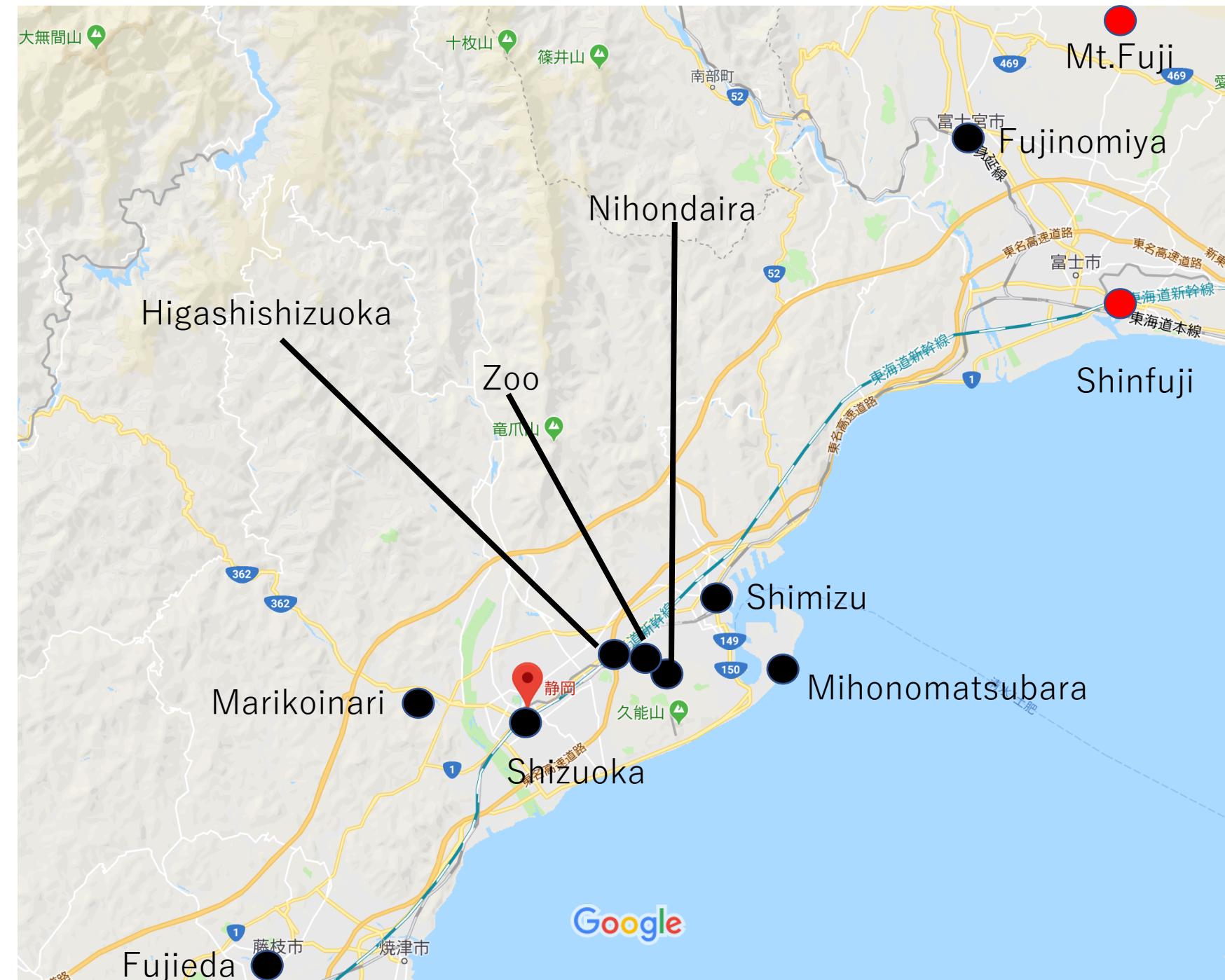
Poland



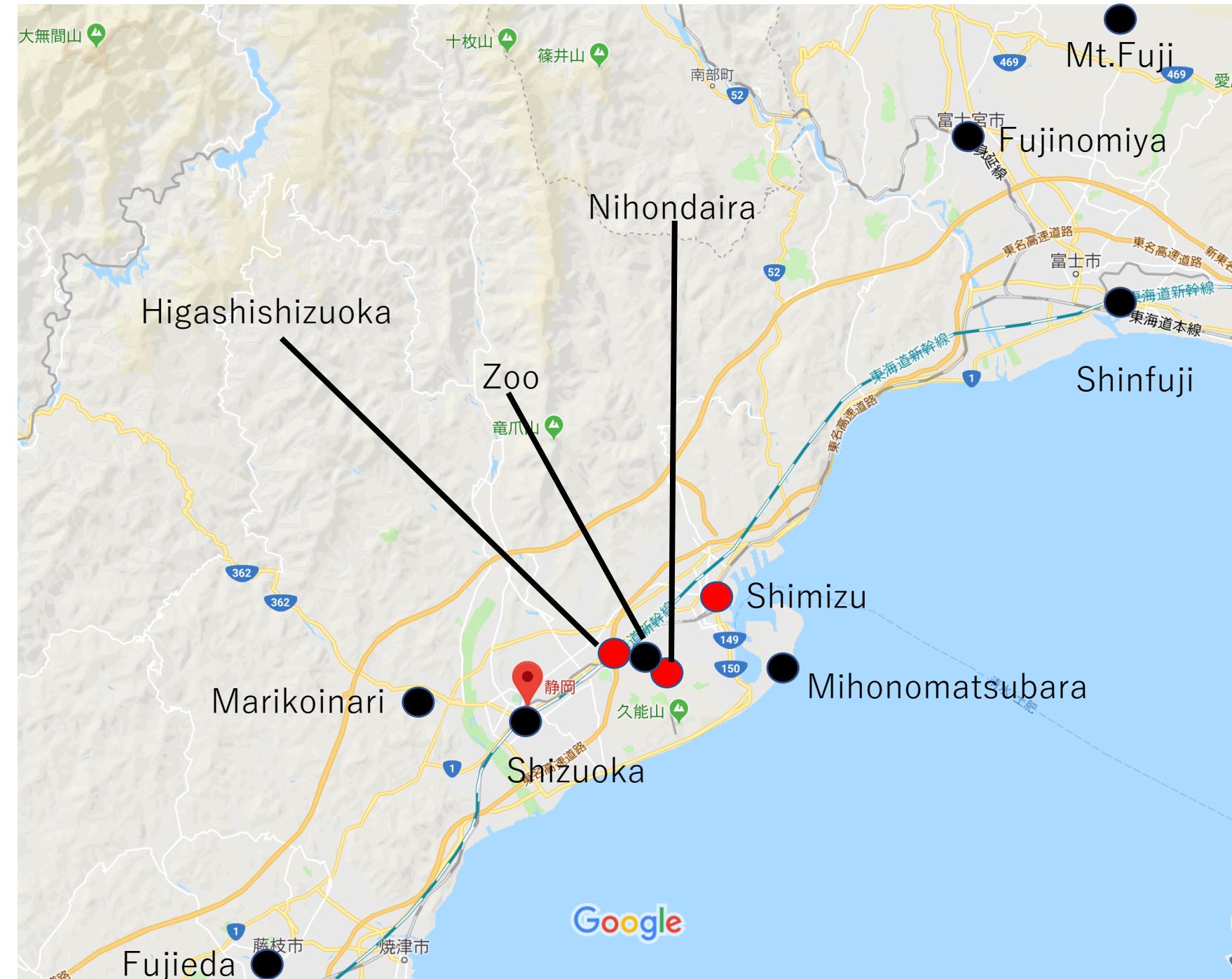
Google

# Poland

Portugal

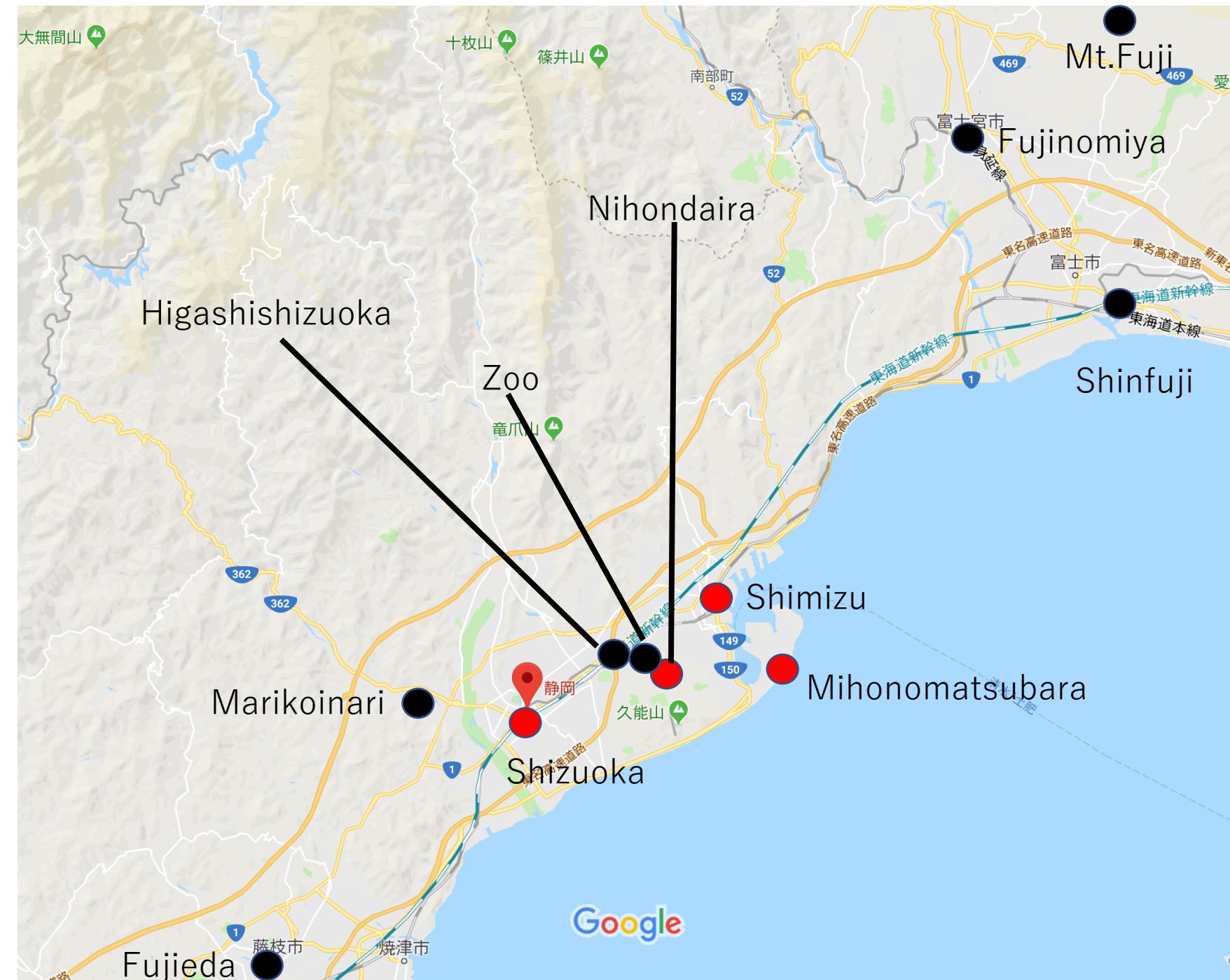


# Portugal



# Vietnam

Malaysia



# Malaysia

Repeat 100 simulations of 9 times of movement with 10,000 trials

- **German**

Germany  
ave.ashizuoka= 4064.86  
ave.mcity= 5935.14

Approximately 40.65% act only in the area around Shizuoka station

- **Australian**

Approximately 2.08% act only in the area around Shizuoka station

Australia  
ave.ashizuoka= 207.92  
ave.mcity= 9792.08

# Discussion

- It will be possible to apply it to Tokyo and Kyoto where there are many tourist attractions.
- When dealing with Tokyo and Kyoto, clustering focusing on various aspects of sightseeing, such as historical buildings and contemporary Japan seems to be necessary.

# Conclusion

- We proposed a mathematical model dealing with the behavior of tourists. We calculated specifically for a simple case of Shizuoka prefecture in Japan.
- The data of foreign tourists traveling in the four cities resulted in most foreign tourists staying in Shizuoka city. It works well with the actual action, but it is too simple.
- Analyzing with the data of foreign tourists moving through 11 sightseeing spots, we found that the transition probability matrix differs greatly from country to country. As a result, it was found that the ratio of Shizuoka station area is greatly different from country to country.
- Based on the result of Shizuoka this time, we analyze data of Tokyo and Kyoto which are popular among foreign tourists.

# Acknowledgement

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