# A Two-region Individual-based Population Model for Evaluation of Regional Population Policies

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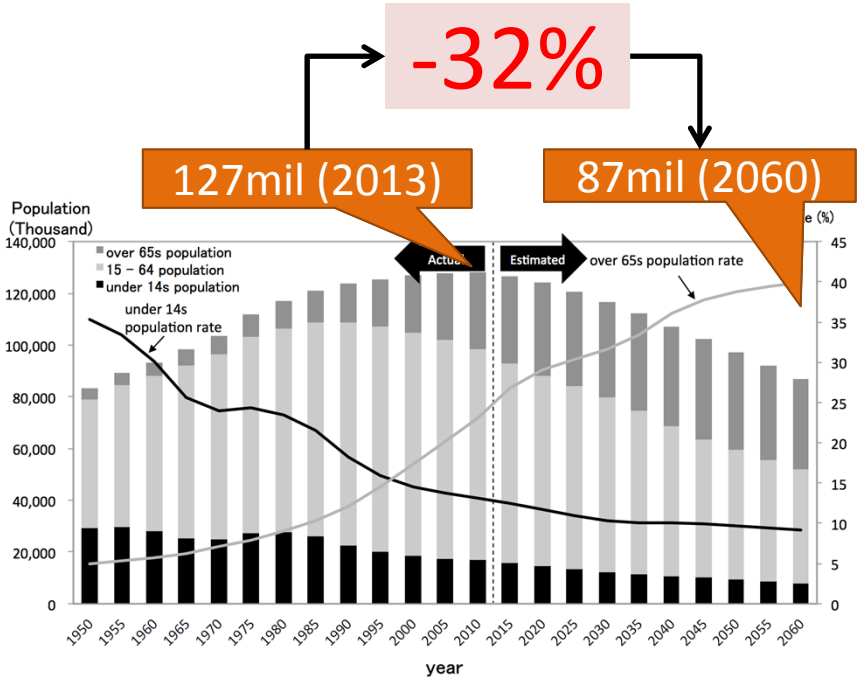
# Background & Objective

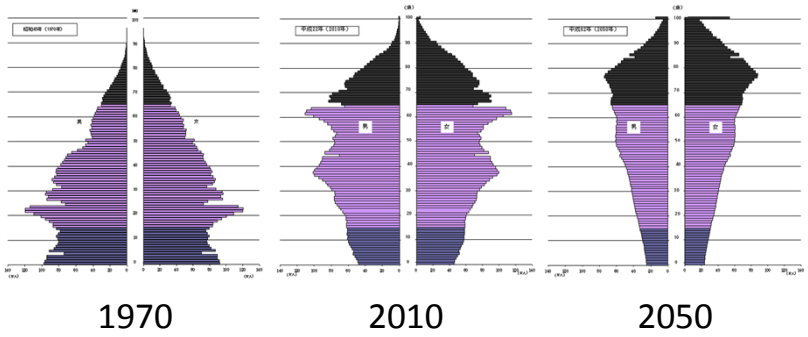
# Depopulation in Japan

– Depopulation and aging of society are proceeding in Japan, and its birthrate is below the replacement level (1.41 in 2012).




Changes of population and population structure
(Created based upon data from Population Census of Japan)

Under-14s : 13% (2013) → 9% (2060)
15 - 64 : 62% (2013) → 51% (2060)
Over-65s : 25% (2013) → 40% (2060)

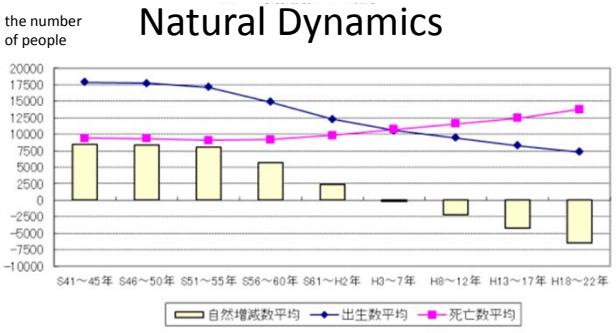



Population pyramids of Japan
(Reprinted from Ministry of Internal Affairs and Communication's website:
http://www.stat.go.jp/data/kokusei/2010/kouhou/useful/u01_z23.htm)

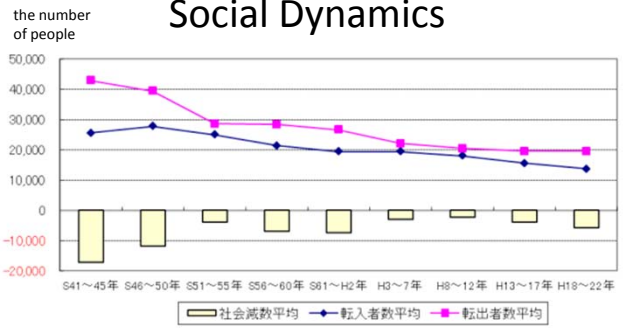
# Depopulation in the Provinces

- Akita (a prefecture in Japan)
  - Depopulation proceeds most rapidly in Japan


Here!

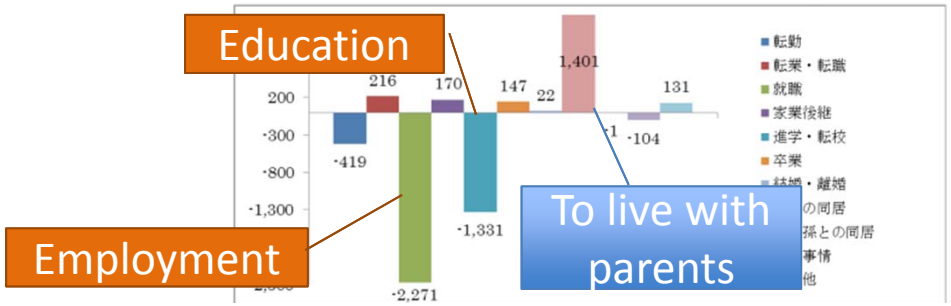



(net increase, number of birth, number of death)




(net increase, immigrants number, emigrants number)

Natural and social dynamics of Akita's population (Reprinted from Akita's population report published by Akita's prefectural office)




The number of net migration for each reasons of Akita (male) (Reprinted from Akita's population report published by Akita's prefectural office)

・・・Excessive outflow could lead to a collapse of social infrastructure.

→<u>Effective population policies are required.</u>

# Objective

Develop a future population estimation model which can evaluate population policies' effectiveness on social dynamics.

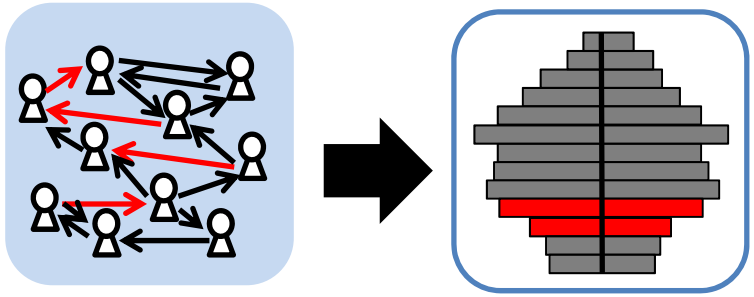
- 3 phases of our research
  - Develop a multi-region population estimation model.
  - Introduce a population policy and estimate the future population.
  - Evaluate the policy's effectiveness by the simulation results.

# Our Population Estimation Model

# Social Simulation Method

- Agent-Based Simulation
  - Modeling individuals as software agents that can recognize the environment and act autonomously.

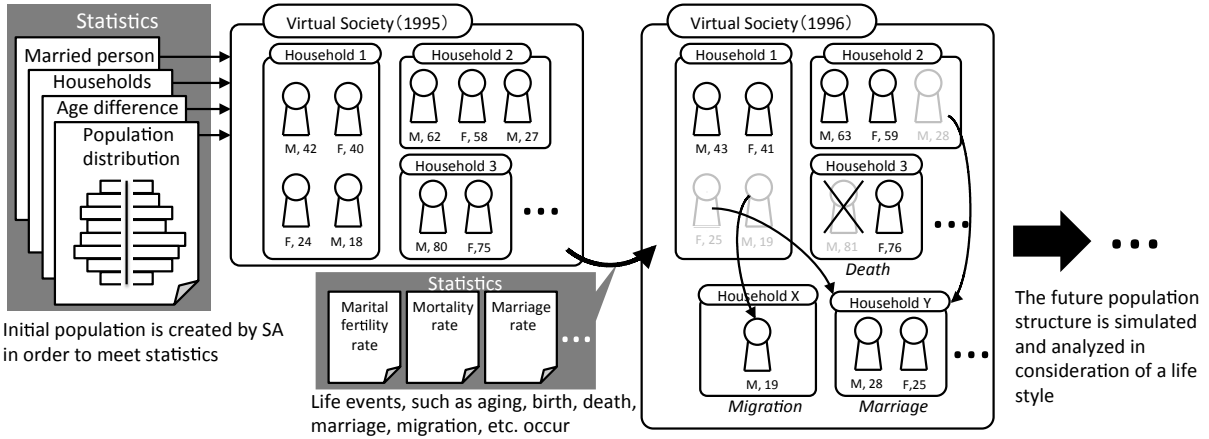
Heiland, F. (2003): The Collapse of the Berlin Wall - Simulating State-Level East to West German Migration Patterns. Agent-Based Computational Demography, 73-96




→ABS enables us to simulate the effects of population policy as bottom-up process.

# Outline of Our Model

- Two-region and individual(agent)-based model
- Each individual belongs to a household located in a region.
- Simulation cycle: 1 year
- Life events: Aging → Marriage → Divorce → Birth → Death → Household integration/separation → Migration




Simulation model

# Configuring Agents' Attributes

Configuring agents' attributes from statistical data.

・・・The number of available data is much smaller than the vast degree of freedom of agents.

→Formulate as a constrained optimization.

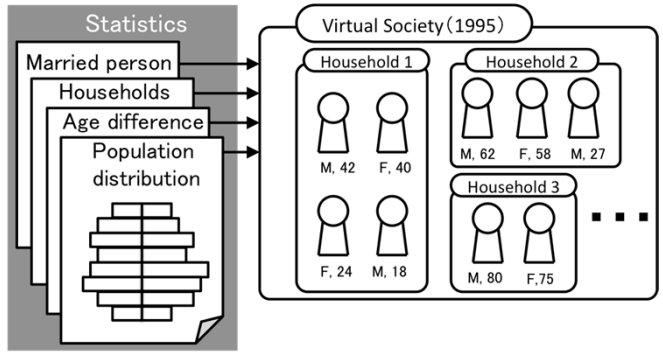
Idea

"Penalty function"

$= \Sigma((\text{statistical data}) - (\text{estimated data}))^2$

→minimize the "penalty function"

by Simulated Annealing




Initial population is created by SA in order to meet statistics

Configuration of agents attributes from statistical data

Repeat various runs of simulation with different attribute datasets

= Ensemble simulation

# Agents' Life Events

- 3 types of life events
  - Regular manipulation
    - Aging
      - All agents get 1 old every year.
  - Applying exogenous probability
    - Birth
      - Probability: According to family role and age
    - Death
      - Probability: According to gender and age

# Agents' Life Events

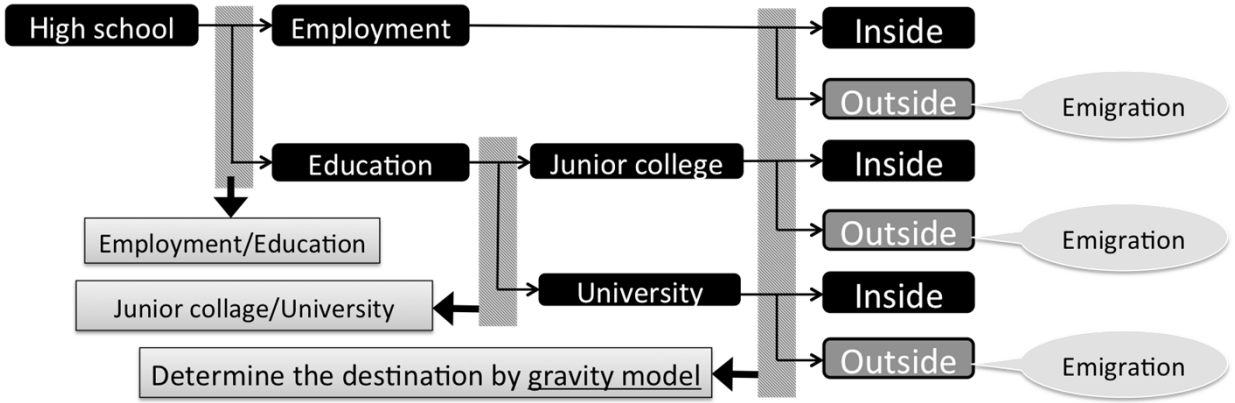
- Formulating as constrained optimization
  - Marriage
  - Divorce
  - Household integration/separation

  e.g. Statistical data for Marriage event
    - Distribution of age differences between first marriage husbands and wives
    - Male marriage rate according to age
    - Female marriage rate according to age

# Inter-regional Migration Model

Develop a model that can evaluate population policies aimed at social dynamical effects.

- Targeted factors: Education, Employment, Transfer
- Each agent decides their action based on quantitative regional data.
- Supposed policy: Increase the number of opportunity for education and employment.




Example of 18-year-old agents (graduated from high school)

# Inter-regional Migration Model

Migrating candidates are determined according to agents' "Age" and "Social role"

- Social role: {Junior college, University, Graduate school, Employment, Others}

the happening timing of migration events: Education, Employment and Transfer

| | Education | | |
|---|---|---|---|
| | Junior College | University | Graduate school |
| Age | 18 | 18 | 22 |
| Social role | Others | Others | University |

"Education" and "Employment"
・・・occur at the timing of graduation

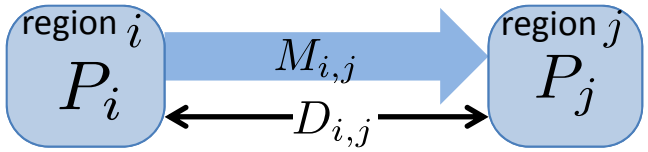
"Transfer"
・・・occurs to employed agents

| | Employment | | | | Transfer |
|---|---|---|---|---|---|
| Age | 18 | 20 | 22 | 24 | 25～65 |
| Social role | Others | Junior College | University | Graduate school | Employment |

# Inter-regional Migration Model

- Migration number is estimated by "Gravity Model".

$$M_{i,j} = G\frac{P_i^{\beta_1} P_j^{\beta_2}}{D_{i,j}^{\alpha}}$$




$M_{i,j}$: Migration number from region i to j

$P_i, P_j$: Population number of region i and j

$D_{i,j}$: Distance between region i and j

$\alpha, \beta_1, \beta_2$: Parameters

e.g. Gravity Model of Education

$P_i$ : The number of students of the graduated educational institute of region i

$P_j$ : Quota of the entering educational institute of region j

$$\Rightarrow \ln M_{i,j} = C + \beta_1 \ln P_i + \beta_2 \ln P_j - \alpha \ln D_{i,j}$$

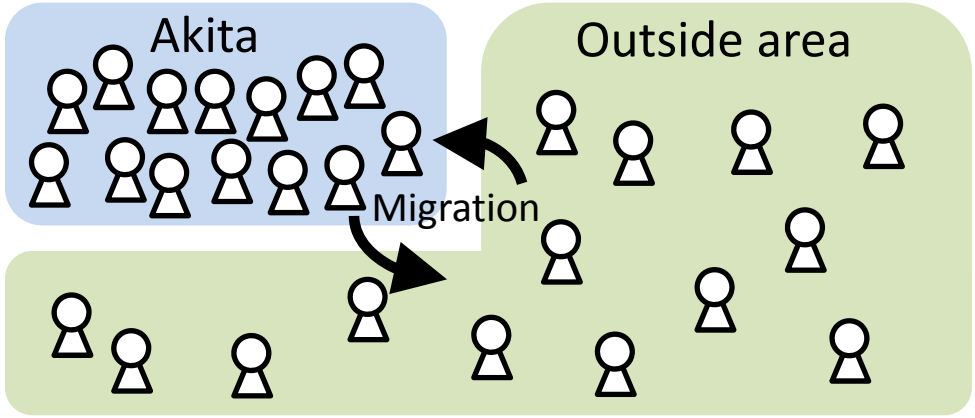
・・・Estimating parameters by Least-squares method.

# Model Application

# Model Application to Akita

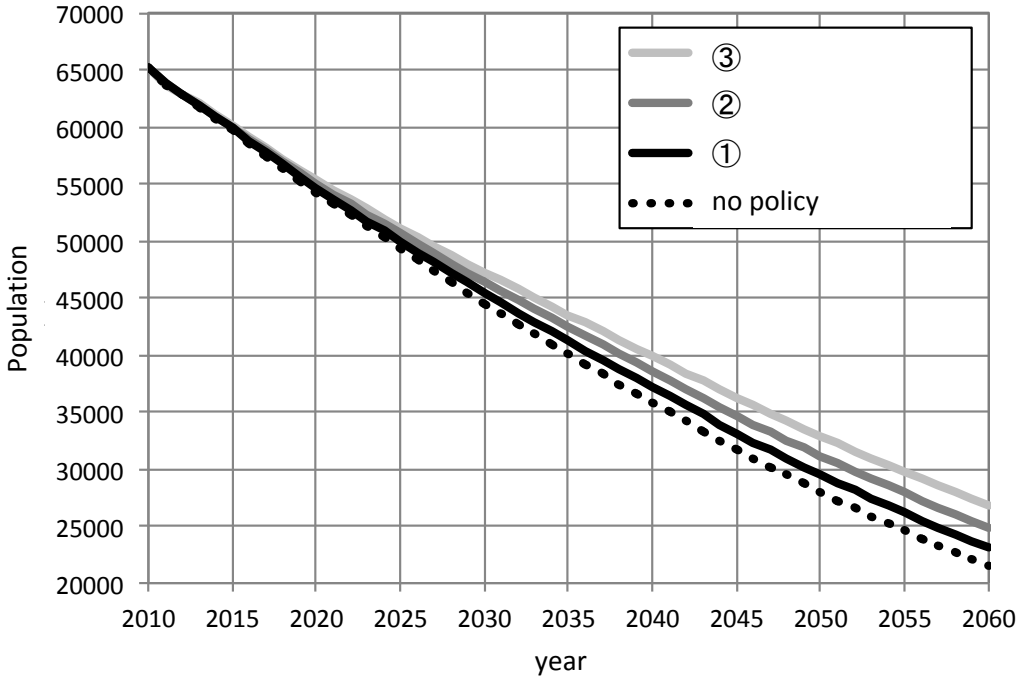
- Regional model
  - Two-region model: “Akita” and “Outside area”
- Introduced Scenarios
  - Increase the number of Quota of higher educational institutes.
  - Increase the number of Employees of private company
  - Raise Birthrate

- Conditions
  - Initial household number: 25,000 (both region)
  - Estimation term: 2010 to 2060 (50 years)



# Simulation Results

① Educational scenario: Quota → 2.0 times
② Employment scenario: Employees → 2.0 times
③ Social scenario: Quota and Employees → 2.0 times
*Comparing with 2010



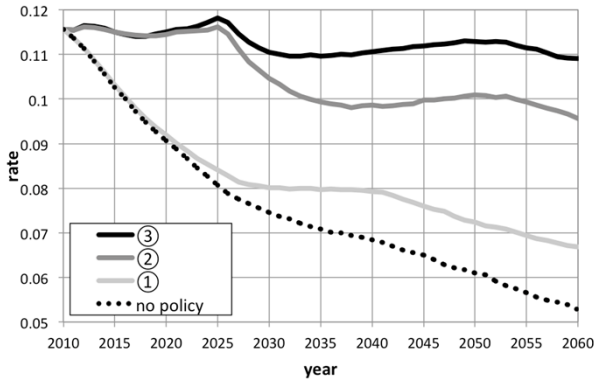

Population change for each scenario

・・・Even though the introduced policies' scales are so large, their effects are very limited.

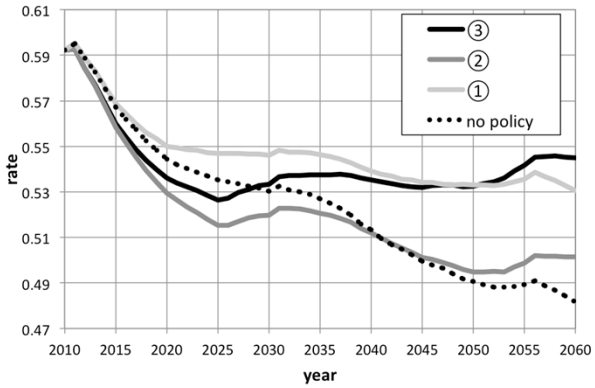
# Simulation Results

① Social scenario: Quota and Employees → 2.0 times
② Birth scenario: Birthrate → 1.3 times
③ Social and birth scenario: Quota and Employees → 2.0 times, Birthrate → 1.3 times
*Comparing with 2010

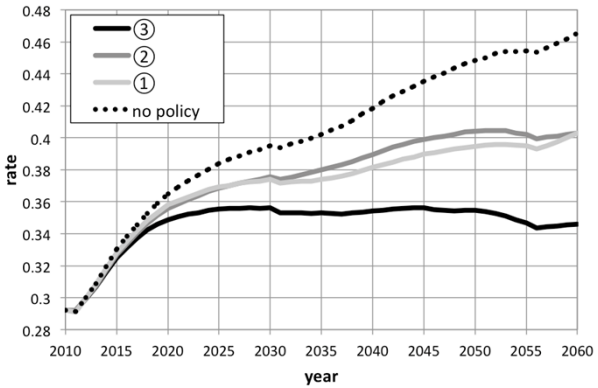
Combination of policies for social opportunity and birthrate recovery might stop the aging of society.




Under-14s population rate change for each scenario




15 - 64 population rate change for each scenario




Over-65s population rate change for each scenario

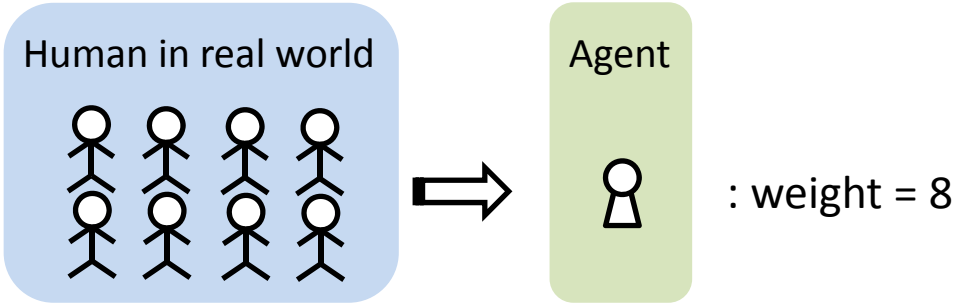
# Further Research

# Our Current Study

Target: migration model

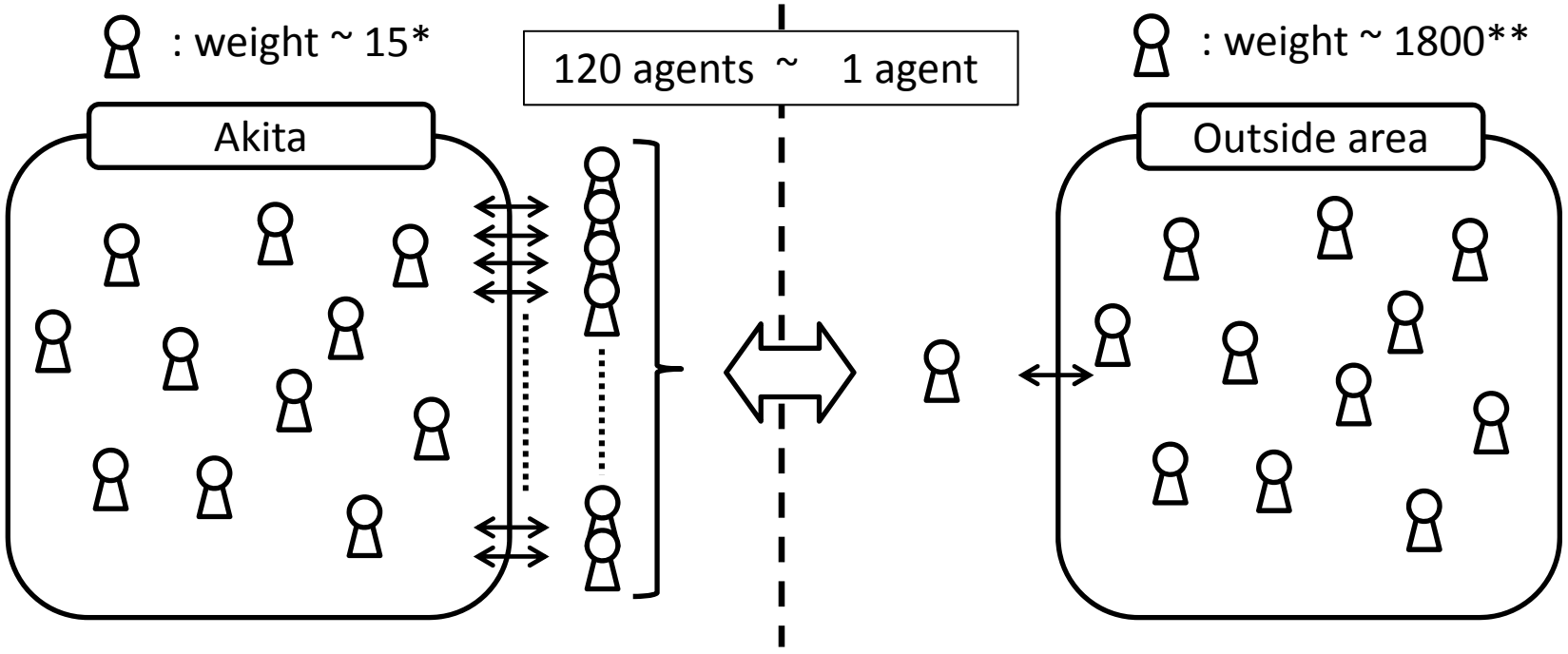
– Current problems

- Each gravity model's parameters are set uniformly throughout the country.
- Migrations caused by marriage or living-with-parents are not well-modeled.
- Agents' "weight" are different for each region.



# Alternative Inter-regional Migration Model

Adjust the agent's weight difference between regions.




* **When each region's households' number is 25,000.

# Conclusion

# Conclusion

- Japan faces serious population problems.
- We developed two-region individual-based future population estimation model.
- By carrying out population policy in the virtual society, we are trying to evaluate its effectiveness.
- To improve validity and accuracy of the inter-regional migration model, we are re-building it.

(This is the end of slids)

(Additional Data)

# Depopulation in Japan

– The characteristic of population dynamics differs by region.

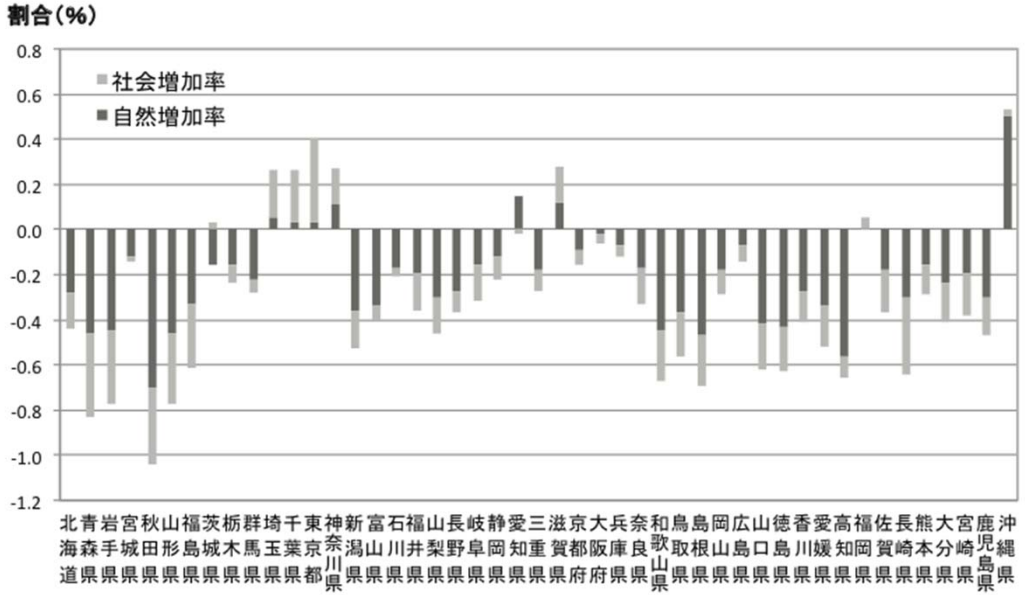



図 4: 都道府県別人口増加率（2010 年）（出典 [6] のデータをもとに作成）

# Depopulation in Akita

- Akita's Depopulation rate is highest in Japan.

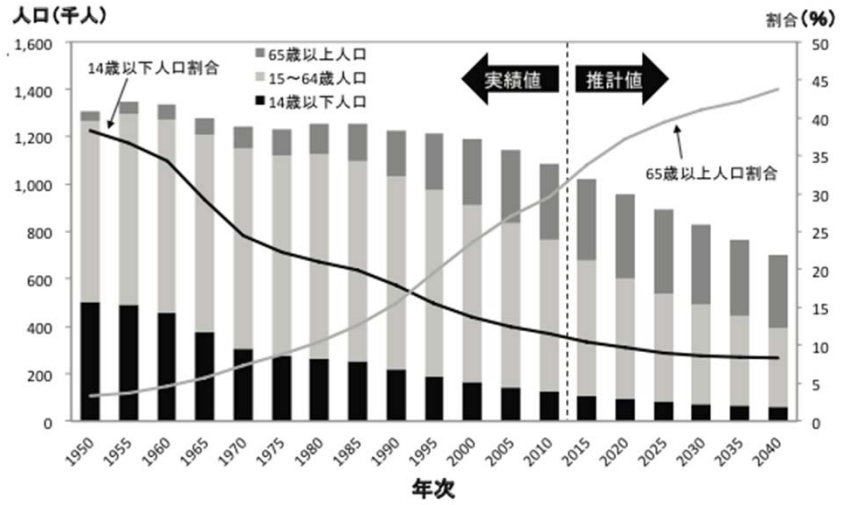
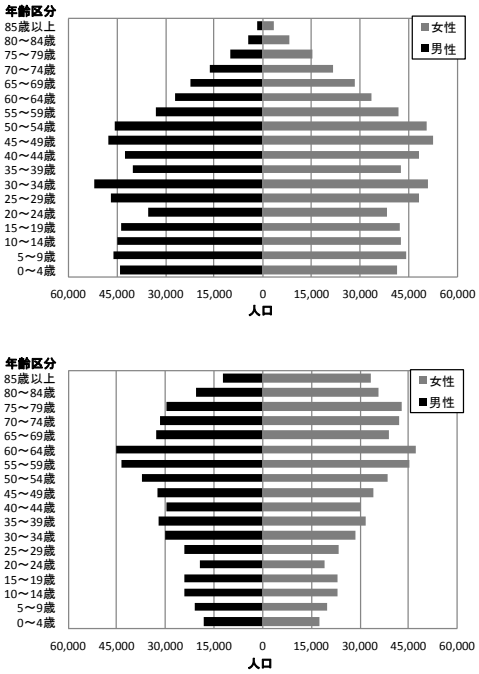



図 5: 秋田県の人口および人口構成の推移（出典 [2] のデータをもとに作成）




Population pyramids of Akita
(above: 1980, below: 2010)

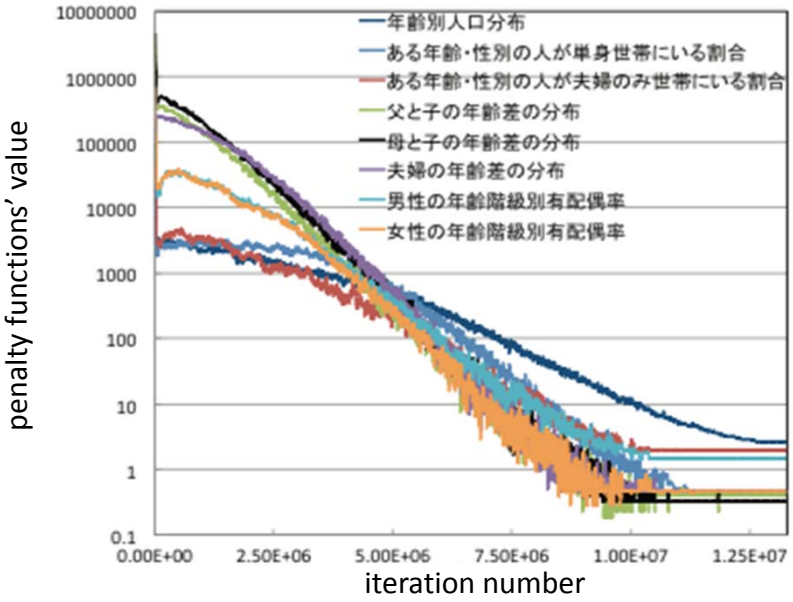
# Configuring Agents' Attributes

- Calculation time
  - OS: Scientific Linux 6.2
  - memory: 12GB (4GB x3)
  - CPU: Intel Core i7 3.07GHz (Quad Core)

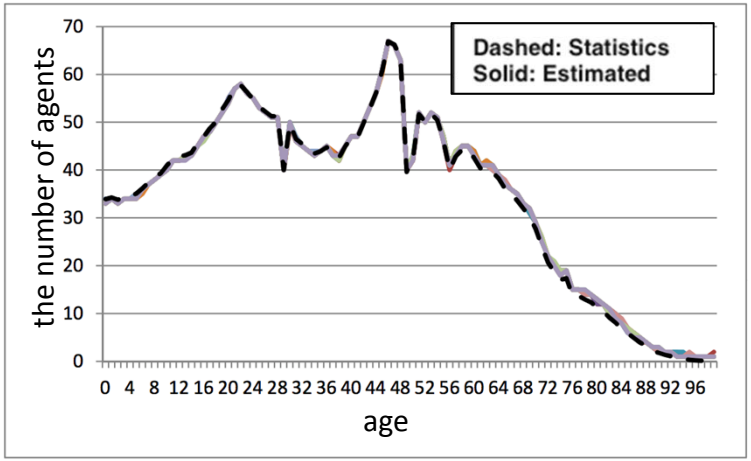
| households | agents | memory usage [MB] | CPU time [min] |
|---|---|---|---|
| 5,000 | 13,970 | 374 | 4.4 |
| 10,000 | 27,988 | 530 | 8.7 |
| 20,000 | 56,014 | 736 | 17.5 |
| 30,000 | 84,054 | 868 | 27.3 |
| 40,000 | 112,090 | 1,059 | 38.0 |
| 50,000 | 140,124 | 1,010 | 48.7 |
| 100,000 | 280,306 | 1,092 | 110.9 |
| 200,000 | 560,676 | 1,308 | 267.1 |
| 300,000 | 841,058 | 1,425 | 522.6 |
| 400,000 | 1,121,426 | 1,568 | 799.2 |
| 500,000 | 1,401,786 | 1,711 | 1,135.1 |

# Configuring Agents' Attributes

- Outcome of optimization



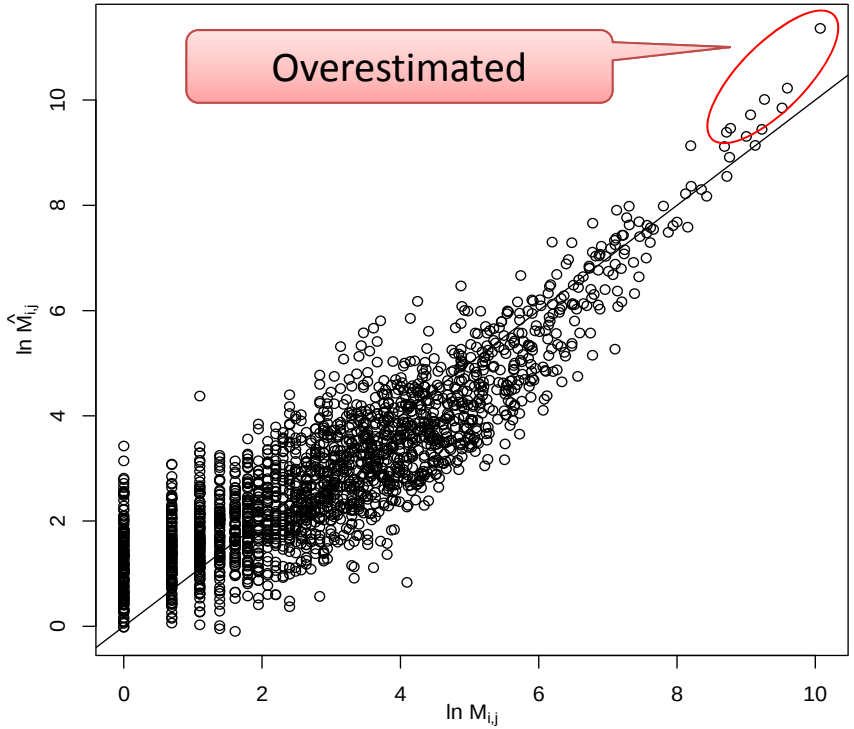

Change of error function values in creation of initial population (5,000 households)




Population distribution of initial agents by age (male)

・・・Obtained population profiles appear near the actual statistics.

# Estimated Errors of Gravity Model




Co-relation between actual and estimated number of students who enter university (male)

# Alternative Inter-regional Migration Model