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Agent-Based Simulation on Women's Role in a Family Line on Civil Service Examination in Chinese History

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Abstract

In this paper, following our previous work on civil service examinations in imperial China, we investigate women's role in a Chinese historical family line using an agent-based simulation (ABS) model with a grid oriented genetic algorithm (GOGA) framework. We utilize a GOGA framework, because our ABS had such large parameter spaces with real values that it required much greater computational resources. First, we studied the genealogical records. Second, based on that study, we implemented an agent-based model with the family lines branched out into two clusters to compare different family norms. Third, using an "inverse simulation" technique, we optimized the agent-based model in order to fit the simulation profiles to real profile data with real-coded GA. From these intensive experiments, we have found that (1) The combined influence of the father, uncle, mother and the aunt has important significance in maintaining a successful family norm, and (2) a particular role of the aunt to pass it on as well.

Keywords:
Agent-Based Simulation, Grid Oriented Genetic Algorithm, Inverse Simulation, Family Norm, Civil Service Examination

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Introduction

1.1

Recently, in the field of family study, the methodology has been gradually changing towards computational sociology. In the recent literature, Kurahashi and Terano (2007) proposed a new method by which an Agent-Based Simulation (ABS) Model uses family trees to study historical and cultural anthropology. They showed the applicability of ABS to historical studies.

1.2

They analyzed successful candidates of the civil service examinations using the ABS model, which is based on the theory of cultural capitals proposed by Pierre Bourdieu (Bourdieu 1979). In the study, they demonstrated that the roles of family members, especially artists are important to transfer the cultural capital. However, there remains several issues to uncover:

1. the expansion of cultural carriers among larger bounds of the family such as aunts and uncles, because the previous study has only covered the range of great grandfathers, grandfathers, fathers, or mothers;
2. the comparison of the influence between cultural carriers such as women's role in a family line to pass on cultural capitals, because the previous study has only covered the cases of the existence or nonexistence of mothers; and
3. the comparison of plural clusters of a family line, because the previous study has only covered single cluster cases.

1.3

Following the work, this paper presents computational and methodological extensions of civil service examinations, family lines, and cultural capitals in China. In this paper, we will demonstrate the roles of mothers and aunts as carriers of cultural capitals from a perspective of reciprocal relationship. The originality of our work resides in the innovative agent-based modelling technology, which uses the grid oriented genetic algorithm (GOGA) framework as the platform to analyze historical issues in an enlarged parameter space. We have developed an ABS based on the viewpoint of the historical demographics and social networks, and analyzed the family system of a particular Chinese family line over a period of about five hundred years. We then have clarified the system of norms maintained by the family through intensive simulation studies on time-series changes of the attributes of family members and then by systematic parameter optimization by inverse simulation (Terano & Kurahashi 1999). Such analysis requires a much more powerful simulation platform, which is able to search a wider range of parameters. For that purpose, we have adopted grid oriented genetic algorithm framework running on PC clusters (Ono 2008). We were able to analyze the women's role as a carrier of cultural capitals even much more widely and deeply than the former study due to the enlarged framework. Such innovative ABS technology can also be applied to analyze diachronic social problems.

1.4

The remaining part of this paper is organized as follows: Section 2 discusses the related work on the family research especially in China and explains the civil service examination system. Section 3 proposes the agent-based simulation model for the analyses. Section 4 describes the grid oriented genetic algorithm framework used in the study, and the intensive experimental results are discussed in Section 5. Section 6 gives concluding remarks and future work.

🌐 Literature Survey of the Family System Research

2.1

The study of the family has been approached from various angles such as: sociology, historical science, anthropology and biology. From a sociological perspective, family commences from fundamental sociological concepts and assumptions. In other words, the sociology of the family consists of the concept of reward, benefit, and exchange, and the assumption regards human as having rational existence (Nye 1982; Hendry 1999). The sociology of the family and its analysis is specified by the notion that the family is one of the social systems and contributes to the functioning of society. This analysis approaches the family from the point of view of a system based on the fundamental concept that the system is a body which organizes and regulates the norms, rules, and customs of the human being. This section will make a brief literature survey of the related work on the family research, with an emphasis on the function of reciprocal allies between families, especially women's role in passing on cultural capitals to the descendants. Such family patterns make it possible that the descendants are able to learn cultural capitals from multi-channels. In imperial China, certain families had constructed reciprocal allies to guarantee their descendants to succeed at the imperial civil service examination.

Analysis of the Marriage System in China

2.2

From the viewpoint of the marriage system of the Han Dynasty in China, which did not have caste systems, a wife-giver has the same status as a wife-taker before her engagement, so the positional relationship is not fixed. The conceptual difference and the positional relationship between wife-taker and wife-giver are illustrated in Figure 1. In the following parts of this paper, a mother and an aunt respectively mean the name from a wife-taker, and a wife-giver, even if it is the same person.
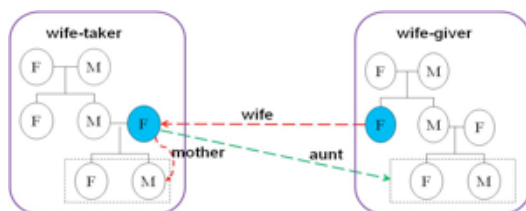

Figure 1. Description of wife-taker and wife-giver

2.3

On the marriage system in China, there are several studies written from the viewpoints of historical science. Ko indicated that since the sixteenth century, the upper class families in the Hunan area in China focused on the levels of women's cultural and literary talents as critical factors for successful marriage (Ko 1994). Furthermore, Mann discussed that, in the

upper class families in late Qing Dynasty, fathers paid their attention to the education of female children and that they often allowed them to take the same level courses as the ones for male children (Mann 1997). It was because (1) the female children or women would educate descendants in their wife-taker families in order to pass the examination for civil service in imperial China, and (2) women in the wife-taker family must have their cultural and moral authority in order to manage the family. Women who mastered empirical cultures at the wife-giver family were the ones who gave the brilliance to the ancestors. They were highly evaluated in their regional societies and the marriage alliances.

2.4

In the old times in China, therefore, highly educated women had an important role through their marriage to pass on the cultural capitals from the wife-giver family to the wife-taker family. However, there are no written studies about the marriage system from the reciprocal viewpoints of family systems, except Ueno (Ueno 2000) has stated that both families kept their relationship, although they were changing their reciprocal relationship over any two generations.

Roles of Women in Passing on Cultural Capitals

2.5

More than 30 years has passed since Bourdieu (1979) introduced the structure of reproduction in relation to cultural capitals and education. He introduced the system of the norm (Habitus, or Habits in English) within a family which reproduces cultural capitals and plays a critical role in the selection of social stratification. The discussion of the wives' roles in a family line began in recent years with regard to the transfer of the cultural capitals through their marital relationship.

2.6

Mann (1991) wrote a paper about the daughter's education for marriage in late imperial China, containing the following quote: "A wise daughter will make a wise wife and mother. And wise mothers rear wise sons and grandsons." This means that the daughters' education could provide the potential to successfully manage the family of the wife-taker. Ko discussed that, highly educated wives or mothers were considered to have good effects on the education of the children of the wife-taker, the activation of cultural activities such as poetry and drawing, and the improvement of morals (Ko 1994). Therefore, in order to educate female children, the upper class families paid much attention to follow their moral schemes.

2.7

Furthermore, there are some cases in which the daughter's married son and his family had important roles in the success of the family line of the wife-giver. However, in almost all written studies, only the effects on the family from a wife-giver were discussed (Ahern 1974). We failed to find any references from the viewpoint of a reciprocal relationship between the wife-giver and wife-taker.

History of Imperial Civil Service Examinations

2.8

In imperial China, there were imperial civil service examinations served as the basic selection system for the recruitment of government officials. It originated from the Han Dynasty (BC.206~AD.220), founded in the Sui Dynasty (AD.581~AD.618), established in the Tang Dynasty (AD.618~AD.907), completed in the Song Dynasty (960~1279) and thrived in the Ming (1368~1644) and Qing (1636~1912) Dynasties when successful candidates who passed the examinations displayed great abilities and reached the heights of politics. The examinations comprised a provincial examination, a metropolitan examination and a palace examination, with an entrance examination for schools in each prefecture as a preliminary step. As it was a qualifying examinations system for high-ranking officials, a few degree types were offered:

- sheng-yuan for the status of students who passed entrance examination held in the prefecture level every year, as a preliminary step.
- chien-sheng for those who outperformed in the junior sheng-yuan students, and were recommended to the central school as students there.
- kung-sheng for those who outperformed in the senior sheng-yuan students, and were recommended to the central school as candidate for particular officials.
- chu-jen for students who passed the provincial examination held in the capital of each province every three years.
- kung-shih for those who passed the metropolitan examination held in the following spring after the provincial examination at the Ministry of Rites in the capital of imperial China.
- chin-shih for those who passed the final step of the palace examination under direct

supervision of the emperor.

2.9

The examination system had run for thirteen hundred years, finally abolished in 1905 near the fall of the Qing Dynasty. According to Elman ([2000](#)), the examination system worked not only to capture and hold the loyal of local-level elites to the state, but also to maintain the cultural unity and consensus on basic values across the whole of China. For over five hundred years, the most important positions within the dynastic government were usually filled through these difficult examinations, and the intersection between the state and the local-level elites put forward the improvement and innovation of the examination system. Even though only a small fraction of those who attempted the examinations passed them and received titles, every year over millions of people from all levels of society attempted them and regarded the system as the most authoritative method for achieving their own personal success through successfully passing such subsequent examinations.

2.10

However, it took a huge investment in time, effort, and training in order to achieve such success. Such candidates set their family, clan, and lineage as the strategic targets of the social reproduction of their community. In the Ming and Qing Dynasties, the school education system accepted only those candidates who already had a good command of the official language and were literate in classical Chinese. It was the responsibility of each house to obtain and maintain these elite positions as the "House of the Bureaucrat" at the initial stage of educating a son and preparing for his entering government service. Furthermore, Elman points out that it is possible for seemingly ordinary candidates to have achieved academic success because they had bureaucrats among their close relatives or affinities to the same lineage, which indicated candidates who came from a family which had the tradition of learning classics and spoke the official language gained superiority for a successful future social and political career. Even though, there was a tendency that certain family lines could produce more successful candidates even from among these elite families. In China, records of family trees had been made from old times and kept as genealogical records: "Zupu". Zupu refers to records relating to family tree and lineage. It was a paternal record from the primogenitor and included name, birth year, year of death, ante mortem achievement, wife's name and her family background, name of children and their achievements, place of residence and other information for each family member.

2.11

In this study, we used the Zupu of the Y family in the Ming and Qing Dynasties to discover the family efforts, especially women's roles to sustain successful descendants outstanding at the imperial examination. The Zupu mainly consisted of two parts: the "Shixi" and "Shibiao" data. The Shixi data generally showed the family tree, and the Shibiao data recorded an individual's profile.

2.12

Changzhou, Jiangsu, the home of the Y Family, is located in the Jiangnan region, which produced the highest number of successful examination candidates, who ranked 1st or 2nd throughout the country in the Ming and Qing Dynasties. It was clear that most of these candidates came from certain families, and there were twenty seven families which kept producing successful candidates for more than five generations during the Ming and Qing Dynasties. Among these families, the Y Family was one of the typical cases, and it produced twenty-two successful candidates during a period of more than twelve generations. This indicates that the implicit family norms may have had an advantage for the examinations, and that culture and habits are actually invisible standards for selection. By the agent based simulation analysis, we began to know why so many such successful candidates were produced from the same family. This was done by employing the Zupu data (genealogical record) of the Y Family.

🌏 Agent Simulations of Genealogical Records

3.1

We prepared the types of data as available for the simulation from the "Shixi" and "Shibiao" Zupu data. The Shixi data described the blood relationship between all family members, and we are able to prepare the adjacency matrix from this data. The Zupu of the Y Family contained data for a total of 1237 persons. The adjacency matrix of 1237×1237 shows the relationship between father and son, and "0, 1" represents this relationship (Figure 2).

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0
2		0	0	0	0	1	1	0	0	0	0	0	0	0	0	0
3			0	0	0	0	1	0	0	0	0	0	0	0	0	0
4				0	0	0	0	0	0	0	0	0	0	0	0	0
5					0	0	0	1	1	1	1	0	0	0	0	0
6						0	0	0	0	0	0	0	1	1	1	1
7							0	0	0	0	0	0	0	0	0	0
8								0	0	0	0	0	0	0	0	0
9									0	0	0	0	0	0	0	0
10										0	0	0	0	0	0	0
11											0	0	0	0	0	0
12												0	0	0	0	0
13													0	0	0	0
14														0	0	0
15															0	0
16																0

Figure 2. Adjacency matrix (Part)

3.2

The Shibiao data was individual's profile, recording occupation, qualified status of the examinations, achievement, art, contribution, qualified status of the examinations of wife's birth family and/or daughter's married family and so on. In the same manner, we prepared the attribution matrix of each person from the Shibiao data. The attribution involves chin-shih (who passed the final step of the palace examination), kung-shih (who passed the metropolitan examination), chu-jen (who passed the provincial examination), kung-sheng (who outperformed in the senior sheng-yuan students and was recommended to the central school as candidate for particular officials), chien-sheng (who outperformed in the junior sheng-yuan students and was recommended to the central school as students there), sheng-yuan (who passed the entrance examination), painter, poet, merchant, birth year, and qualified status of the examinations of wife's birth family and/or daughter's married family and so on. Among these elements, the attribution of qualified status of the examination (chin-shih, kung-shih, chu-jen, kung-sheng, chien-sheng and sheng-yuan), and the attribution of individual's expertise in painting, poetry, or his philanthropic act (painter, poet and merchant) are represented by 0, 1. Especially, if he married a women and/or his daughter married a man whose family had one or more members (father of the family, for instance) who succeeded in the imperial examinations with a qualified status of chin-shih, kung-shih, chu-jen, kung-sheng, chien-sheng or sheng-yuan, then the attribution of his wife and/or his daughter is represented by 1, or else is represented by 0 (Figure 3). Each member has one candidate status for the imperial civil service examination and also has multiple statuses of his occupation, art, his wife's birth family and his daughter's married family. We reproduce the family tree following the relationship and attributions in the two matrices, and implement the simulation based on this family tree.

	chin-shih	kung-shih	chu-jen	kung-sheng	chien-sheng	sheng-yuan	painter	birth year	wife	daughter
1	0	0	0	0	0	0	0	1468	0	0
2	0	0	0	0	0	1	0	1492	0	0
3	0	0	0	0	0	0	0	1492	0	0
4	0	0	0	0	0	0	0	1492	0	0
5	0	0	0	0	0	0	0	1492	0	0
6	1	0	0	0	0	0	0	1518	0	0
7	0	0	0	0	0	1	0	1522	0	0
8	0	0	0	0	0	0	0	1522	0	0
9	0	0	0	0	0	0	0	1522	0	0
10	0	0	0	0	0	0	0	1541	0	0
11	0	0	0	0	0	0	0	1545	0	0
12	0	0	0	0	0	0	0	1548	0	0
13	0	0	0	0	0	1	0	1544	1	0
14	0	0	0	0	0	1	0	1548	0	1
15	0	0	0	0	0	0	0	1550	1	1
16	0	0	0	0	0	0	0	1550	0	0

Figure 3. Attribution matrix (Part)

3.3

An assumption of this study is that family lines that have many excellent descendents succeeding at the imperial civil service examination not only maintain cultural transmission by the family members, but also make use of the marriage between families as a norm to pass on cultural capitals to their children. In "La Distinction", Bourdieu (1979) had defined cultural capitals as the output both from tangible and intangible properties related to culture in the broad sense of the term. In addition, he classified individual's cultural capitals into linguistic ability and other abilities including drama, painting and poetry. Based on such cultural capital theory, we have defined two types of cultural capitals in this study: one is knowledge capital, which is the ability of speaking and writing the special official language, required in the imperial examination; the other is artistic capital, which refers to the individual's skill in painting.

3.4

In this study, each family member is modelled as an agent. The outline of the agent-based simulation is as follows:

- Each agent transmits cultural capitals from parent to child, from great-grandfather to great-grandson, from grandfather to grandson, from uncle and aunt to nephew, in a face to face way along the family tree shown by the adjacency matrix.
- Children have in-born characteristics of knowledge and artistic. When the simulation starts, the characteristics are given to children as random numbers between 0.0 and 1.0.

- Where there is a successful examination candidate with a qualified status on the side of the mother's birth family, his cultural capitals will be transmitted from the mother to the child in the same manner.
- Where there is a successful examination candidate with a qualified status on the side of the aunt's married family, his cultural capitals will be transmitted from the aunt to the nephew in the same manner.

3.5

Further, we attribute the regular cultural capital transmission to the two channels: school and family, which also come from Bourdieu's theory of cultural capital, where the variety of knowledge, accomplishment, expertise, liking and sensitivity was assumed as a kind of cultural capital that each individual had accumulated through his/her family circumstances and school education. Based on this hypothesis, we take into account that the degree of a child's cultural capitals depends on the synthetic result of cultural capitals transmission functions, not only from school education but also from his family circumstances. We then present two formulas to describe the operation of cultural transmissions between agents as follows:

$$cl_c^k = m_0 \cdot (ps_c^k + r_a \cdot ps_c^a) + \sum_{i=1}^{n} m_i \cdot (cl_i^k + r_a \cdot cl_i^a) \quad (1)$$

$$cl_c^a = m_0 \cdot (ps_c^a + r_k \cdot ps_c^k) + \sum_{i=1}^{n} m_i \cdot (cl_i^a + r_k \cdot cl_i^k) \quad (2)$$

each m_i acts as a discount rate (the transmission from the great-grand father to child, for instance). And the value of i goes from 1 to 6, including the different family members such as great-grandfather, grandfather, father, mother, uncle and aunt. The variables are explained in Table 1.

Table 1: Varibles and their descriptions used in the cultural capital transmission function

---

Variable	Description
cl_c^k	knowledge cultural capital of the child
cl_c^a	artistic cultural capital of the child
ps_c^k	the inborn characteristic of knowledge cultural capital of the child
ps_c^a	the inborn characteristic of artistic cultural capital of the child
cl_i^k	knowledge cultural capital of member i
cl_i^a	artistic cultural capital of member i
r_a	influence rate from artistic cultural capitals to knowledge cultural capitals
r_k	influence rate from knowledge cultural capitals to artistic cultural capitals
m_0	cultural transmission rate from school education
m_i	cultural transmission rate from family member i

3.6

Each agent interacts with other agents and takes action to learn in order to accumulate its cultural capitals. Figure 4 shows the pseudo code of two kinds of interactions between agents, by which the cultural transmission process is implemented based on the above two formulas. The cultural transmission process along the family tree through each individual is called a simulation cycle in this study.

```
At each cycle
    start
      for each Agent i along the family line
    InteractionS (School, Agent i)
    InteractionF (Agent j, Agent i)
      end for
    end

Function InteractionS (School, Agent i)
    start
        TransmitCulturalCapital (School, Agent i)
    end

Function InteractionF (Agent j, Agent i)
    start
        Search all Agent j < > Agent i
        if (Agent j is the great-grandfather or grandfather or father
                    or uncle of Agent i) then
        TransmitCulturalCapital (Agent j, Agent i)
         end if
        if (there is a successful candidate in mother's birth family) then
        TransmitCulturalCapital (mother, Agent i)
         end if
        if (there is a successful candidate in aunt's married family) then
        TransmitCulturalCapital (aunt, Agent i)
         end if
    end
```

Figure 4. Pseudo code of interaction and action between agents

3.7

Because the imperial civil service examination system selects officials only based on individual's linguistic ability of speaking and writing the special official language, we have clarified as knowledge cultural capital in this study. Also only knowledge cultural capital should affect the success in the examinations. Artistic cultural capital should not directly affect the rate of success in the examinations. It might affect knowledge cultural capitals through artistic cultural capitals, since as Bourdieu has stated that artistic and knowledge cultural values have correlation influences ([Bourdieu 1979](#)). The agents take action based on the above two kinds of interactions to implement cultural capital transmission. At the same time, they have parameters that decide each pattern of action. The parameters are the rate of cultural transmission from family members (great-grandfather, grandfather, etc) to child, and the coefficient between two types of cultural capitals. They are included in the formulas (1) and (2) as the variables of m_i, r_k and r_a. These parameters are common to all the agents, which are described as follows and illustrated in Figure 5:

- Who transmits cultural capitals (great-grandfather, grandfather, father, mother, uncle or aunt)?
- Degree of effect by school education (cultural transmission rate from school education to child (m_0)).
- Degree of effect by family circumstances (cultural transmission rate from great-grandfather, grandfather, uncle, father to child (m_1, m_2, m_3, m_4)
- Degree of effect by reciprocal alliance (cultural transmission rate from mother's birth family (m_5) and from aunt's married family (m_6))
- Influence rate from knowledge cultural capital to artistic cultural capital (r_k)
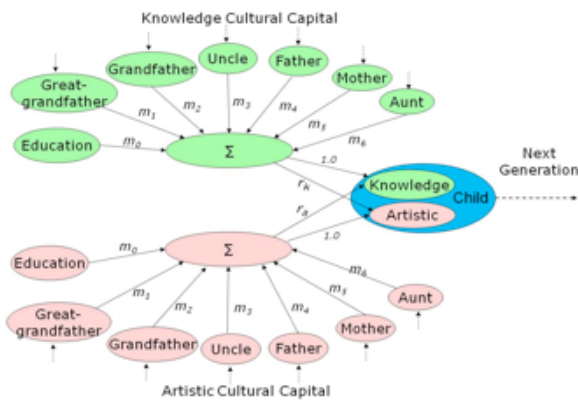- Influence rate from artistic cultural capital to knowledge cultural capital (r_a)

Figure 5. The common parameters in cultural transmission process

🌐 Inverse Simulation by GOGA Framework

4.1

Here, we describe the principles of inverse simulation compared with normal forward simulation in order to explore the vast parameter space of multi-agent based simulation ([Terano 2007](#)). Figure 6 and Figure 7 show the agent simulator model and pseudo code of the inverse simulation.
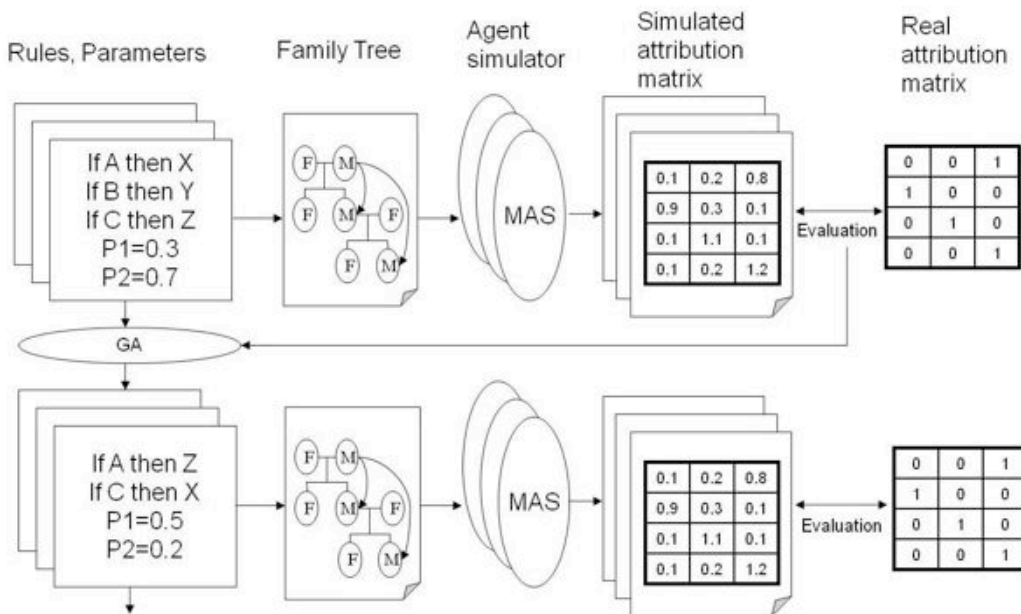

Figure 6. Inverse simulation model

```
Inverse-Simulation (realData)
start
        set parameters and rules of each society to random
                for each society      in the world
                    Create-Society (parameters, rules)
                end for
        while generation < maxGeneration
                for each society in the world
                    Simulate-Society (parameters, rules)
                        fitness <- fitness-function(realData)
                end for
        SelectRecombinate-Society (fitness)
        end while
optimumParameters-and-rules <-
                parameters and rules of society[maxFitness]
                return optimumParameters-and-rules
    End
```

Figure 7. Pseudo code of inverse simulation model

4.2

Generally, inverse simulation uses an optimization technique, such as Genetic Algorithm (GA) to search for appropriate parameters which correspond to a fitness function in relation to the real world. However, because there are too many possible parameters and rules in inverse simulation, it takes a long time to evaluate the enormous amount of numerical candidate solutions. However, as the multiple candidate solutions in GA are evaluated independently, the search time will be shortened if all the evaluation tasks are executed in parallel with multiple CPUs. A Grid (Ian & Carl 2004) as a parallel calculation platform develops large scale computation capability by connecting calculation resources such as PC cluster dispersed geographically over the Internet which mutually performs parallel computation. Imade et al. (2004) proposed a framework, called "Grid–Oriented Genetic Algorithm (GOGA)", for enabling researchers of GAs to easily develop GAs running on the grid, and they confirmed the applicability of GOGA for bioinformatics by applying it to a fine–gene genetic network estimation problem. Ono et al. (2008) improved and proposed the GOGA framework 2, which aims at developing GA running efficiently and speedily on the gird. The experiment showed good scalability from 1 to 100 nodes on the gird test–bed. In this study, we make use of GOGA framework 2 to implement an agent–based simulator model in order to analyze success family norms along a family line through five hundred years. Further, we employ the real–coded GA instead of the integer–coded GA, which we used in the previous experiments. The real–coded GA enlarges the parameter space to find the optimum parameter sets in order to fit the simulated profile data to the real profile data. Under such circumstances, the grid computing resources will enable us to speed up the evaluation of a large numbers of candidate solutions in GA. We employ Minimal Generation Gap model (MGG) (Sato 1997) as the basic generation–alternation model, and Unimodal Normal Distribution Crossover (UNDX) (Ono 1997) for the crossover operator. The employed algorithms are commonly used in real–coded GA applications in the literature.

4.3

The grid environment assumed in this study consists of user terminals and multiple PC clusters, connected by a network. Each PC cluster includes a login node and many computation nodes. Based on the UNDX+MGG algorithm, the master–worker model is adopted to implement parallel GA computation, where the node that deals with the population data and the processes except calculation of evaluation values is called *master*, and the multiple nodes that calculate evaluation values are called *workers*. As shown in Figure 8, the *master* node has three kinds of threads cooperating with each other. The *main thread* initializes data such as the population and the individual queue. The *generation–alternation thread* handles the process of generational alternations. The MGG algorithm implements generation–alteration as follows: 1) choose two parents randomly from the present population, 2) make multiple children by applying the crossover operator (UNDX, for instance) to the selected parents, 3) put the children to the individual queue, 4) wait until the evaluation of all children finishes or the terminal time set by a user passes, 5) select two individuals from the population containing the parents and their children to replace the original parents,

by applying best selection and rank-based roulette selection, and 6) repeat the steps from one to five. The *client thread* communicates with a *worker*: request the *worker* to evaluate the children from the individual queue by sending them to the *worker* and notifying the *generational-alternation thread* when the evaluation of children finishes. A *worker* receives a request for evaluating individuals from the *master*, performs fitness evaluation of the individuals by comparison of the real and experimentally-observed cultural capitals data, and returns the evaluation values obtained in parameter optimization.
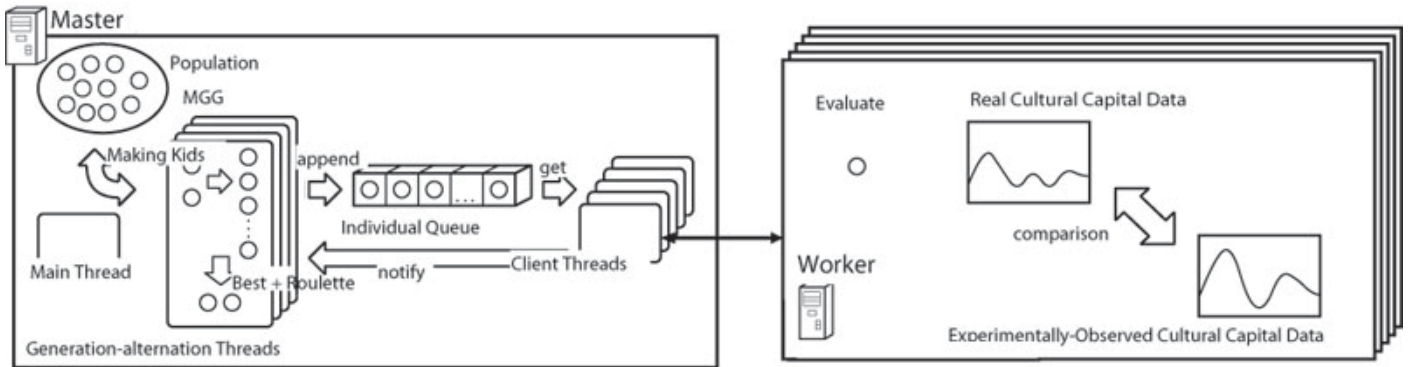
Figure 8. Parallel real-coded GA (UNDX+MGG)

4.4

As an object-oriented framework written in Java, the GOGA framework 2 provides convenient programming interfaces. Based on these interfaces, we easily developed inverse simulation by employing real-coded GA (UNDX+MGG). As discussed before, cultural capitals are transmitted to the child by the system of norms, and the parameters which characterize the norms determine the transmission process along with the family line. We execute agent simulations in parallel with different initial values, because a lot of societies evolve in parallel on the grid by utilizing the GOGA framework. The profile information of all the agents, which appears as a result, is compared with the actual profile information based on the attribution data prepared by Shibiao. The data of these profiles were employed after tallying by each agent. The objective function sets the error by the mean square of this simulator profile information and actual data profile information. The objective function is as follows:

$$\min : Fitness = \sum_{i=1}^{n} \sum_{j=1}^{m} (c_{ij} - sc_{ij})^2 \quad (3)$$

4.5

Where n is the number of agent, m is the number of cultural capitals, c_{ij} is real cultural capitals degree, and sc_{ij} is simulated cultural capitals degree. We selected the better of the models by way of roulette based on the values of the objective functions of each generation and produced an agent model that had the next generation parameters by the real-code GA (UNDX+MGG). As a result, we could obtain an agent model that indicates results similar to the actual profile information. By analyzing the parameters of this model, we could estimate the strategies of the family lines which produced many successful examination candidates.

🌐 Experimental Results and Discussion

5.1

Initially, we built the network of the Y family, where each individual is modelled as a node. There are 1237 members along the family line through 500 years, so we obtain the size of the network as 1237. The characteristics of the network structure of the individuals are strongly influenced by the special family norms within those individuals. In this sense, the personal-network is an important concept which transmits the family lifestyle to the descendants. A new family image becomes clear as a recognized network, by knowing who the most important person is among family members. Such tendencies are shown in the structure of family members as the dyad, the triad, transitivity and chain networks (Wasserman 1994; Carrington 2005).

5.2

According to the "0, 1" values in the adjacent matrix which represent the relationship between father and son, we draw lines from those father nodes to their son nodes as shown in Figure 9. We fill each node with different colours based on those "0, 1" values that denote his title at the civil service examination and his painting skills in the attribute matrix, where a red node is a successful candidate who attempted the examination, passed them, and received titles as chin-shih, kung-shih, chu-jen or kung-sheng, a green node is a successful candidate who

received title as chien-sheng and sheng-yuan, a blue node is a painter, and the remaining nodes are neither successful candidates nor painters, marked black. Figure 9 shows parts of the network of the Y family, including 600 nodes. An interesting phenomenon is that a seventy percent candidate success rate is concentrated in the branch of node No.33, called the South Branch of the Zupu records of the Y family while all the other branches from node No.34 to node No.61 held only thirty percent success rate.
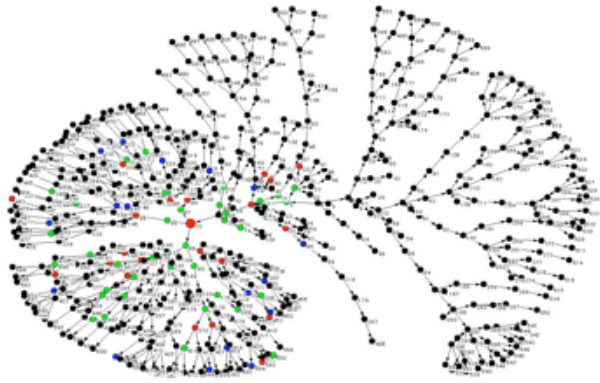

Figure 9. The network of 600 individuals in the Y family

5.3

Based on the above analysis, we classified the whole family line into two clusters, called successful and unsuccessful cluster, and then we compared the strategies of each cluster. The experimental configurations of the agent simulator model of inverse simulation through the GOGA framework 2 are as follows: selection by best and rank-based roulette, crossovers of MGG: 100, alpha of UNDX: 0.5, beta of UNDX: 0.35, number of societies: 50, number of generations: 2000, where the value of alpha and beta in UNDX were set according to the suggestion in (Ono 1997). The inverse simulation using a real-coded GA optimizes the parameters of the transmission functions, and the correlation influence rates between knowledge and artistic cultural capitals. As the result of the experiments, we obtained the following parameters and functions after executing the 2000 generations 10 times (Table. 2).

Table 2: The result of the experiments

Parameter	The result of Multi-Agent Based Simulation
People who transmit cultural capital to child	father, uncle, mother, aunt
Education effect	3%
Effect by mother	28%, if maternal grandfather is a successful candidate.
Effect by aunt	6%, if father in aunt's married family is a successful candidate.
Influence rate from artistic cultural capital to knowledge cultural capital	100%
Influence rate from knowledge cultural capital to artistic cultural capital	0%
Transmission method of cultural capital	Both knowledge cultural capital and artistic cultural capital are transmitted to the child from parents.

5.4

The above matters are assumed in the family as transmission functions of cultural capitals that we described in formula (1) and (2), Section 3. The results in Table 2 discovered that the influence rate from artistic cultural capital to knowledge cultural capital (r_a) is 100% while the influence rate from knowledge cultural capital to artistic cultural capital (r_k) is 0%. This result indicates that there is a strong bond in the exchanges between artists and intellectuals. The conclusion that both knowledge cultural capital and artistic cultural capital are transmitted from parent to child explains the cultural relationship between brothers and sisters, which is still observed in the present society.

Relationship between Grandfather and Uncle

5.5

From the above results, we see that father and uncle play the most important roles in the family for transmitting cultural capitals to a child, and the influence of the father is a little stronger than that of the uncle. On the other hand, the great-grandfather has little influence on his great-grandson, which indicates that very few cultural capitals are transmitted to the child over the distance of three generations. In a previous work, the role of the grandfather was important. Here, the grandfather has little importance. His role is replaced by the uncle's one. This is due to China having a large extended family system where all the family members live together in the past. Thus the uncle inherited the cultural capitals from the grandfather and then passed them on to the child indirectly.

Roles of Female Members through Marriage

5.6

The simulation results indicate that the roles of mother and aunt in a successful cluster are influential. Figure 11 depicts that the values of the influence are respectively 28% and 6% from mothers and aunts and that the mothers' influential effect is approximately equal to fathers' or uncles'. This results support the statements of Ko and Mann on the importance of women's education in the marriage system in China that we reviewed in Section 2. The experimental results with quantitative evaluation will contribute to support conventional historical researches with qualitative document investigations or field work.

5.7

Furthermore, from these experiments we discovered the influential effect of aunts. Ko had shown that in the cases that families, where they kept an equal relationship of marriage over generations, brought up their children with each other. She had described that adoption of children appears to be a strategy that was used among the Wujiang (the lower current area along Yangtze River) elite families to supplement marriage alliances, or to enhance a son's educational opportunities. She has said that the families utilized such kinds of strategies to provide more chances in order to educate their children. Figure 10 illustrates such reciprocal relationship. From a wife-giver to wife-taker perspective, the cultural capitals pass on to the next generation from maternal father to daughter and from mother (daughter) to son, as pointed out by the red solid line, which indicates an invisible cultural transmission described by the red dotted line. On the other hand, the green solid and dotted line explained the cultural transmission from a wife-taker to a wife-giver perspective. Figure 10 indicates that such a norm system can help rebuild the family fortunes when there is a marriage with girls from "good families"(wife-taker) or girls married to "good families"(wife-giver).
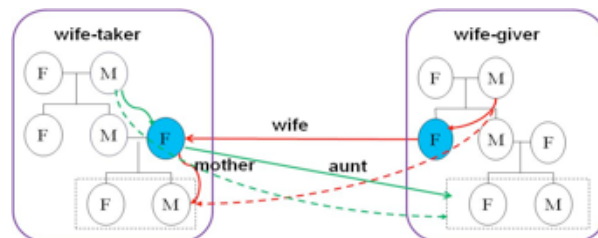

Figure 10. The reciprocal relationship between wife-taker and wife-giver

5.8

Although written studies have analyzed the influential effects from a wife-giver to a wife-taker, there was little opposite discussion on the influential effects from a wife-taker to a wife-giver. Our simulation experiments suggest that even though the influential effects by the aunts, which are relatively small when compared to that of mothers, maintained the norm of a reciprocal relationship between families. This topic must be further investigated.

Comparison between two family clusters

5.9

Figure 11 shows the different strategies in the successful and unsuccessful clusters in the Y family. The conclusions are summarized as follows:

- The role of the mother has almost the same influence as the father and uncle in passing on both knowledge and artistic cultural capitals to a child.
- A particular role of the aunt to transmit cultural capitals as well.
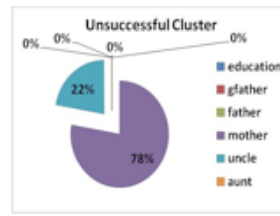
Figure 11a   **Figure 11b**

Figure 11. Family influence in a successful cluster (left) or unsuccessful cluster (right)

5.10

Furthermore, the following interesting phenomena are found as the characteristics of the strategies for success:

- The father has the same responsibility as the mother to educate the child, or if only the mother educates the child and the father's cultural capitals transmits little to the child, then it is difficult for the child to grow up to be a successful candidate. This can be inferred from the result in the right hand side of Figure 11.
- The combined influence of the father, uncle, mother and aunt has important significance in maintaining successful family norms.
- Both the mother in wife-taker and aunt in wife-giver situations play important roles to success.
- Table.1 discovers that the artistic cultural capitals has great positive influence on the advancement of a child's knowledge cultural values with a percentage of 100%, while the inverse effect is little, which indicates that a child has more possibility to grow up to be a successful candidate when he has more chances to appreciate art.
- The education system is helpful to the child.

5.11

In order to confirm the results, we compare it with the general linear model (GLM), specified as follows:

$$\hat{c} = \theta_0 + \sum_{i=1}^{n} \theta_i^k \cdot cl_i^k + \sum_{i=1}^{n} \theta_i^a \cdot cl_i^a + \varepsilon \qquad (4)$$

5.12

The above formula infers the successful descendants along the family line in the civil service examination in imperial China through five hundred years, where $\hat{c}$ is the reasoning result, n goes from 1 to 6 again, including the different family members as described in section 3, the variables of $cl_i{}^k$ and $cl_i{}^a$ represent the two types of cultural capital of member i respectively, $\theta_i{}^k$ and $\theta_i{}^a$ are regression coefficients, and ε is the error term. When the p-value is smaller than or equal to 0.05, the output parameters for the successful cluster are knowledge capital of father (0.078), uncle (0.081), mother's birth family (0.096), and artistic capital of uncle (0.150), while the parameters for the unsuccessful cluster are knowledge capital of mother (0.275) and artistic capital of father (0.155) and uncle (0.233), which are mostly respected to those findings by agent-based simulator although it did not find the role of aunt in maintaining a successful family norm.

5.13

The root mean square (RMS) between real cultural data and experimental cultural data by our agent-based model via inverse simulation is 0.367 for the successful cluster and 0.130 for the unsuccessful cluster while RMS of each cluster under GLM is 0.504 for the successful cluster and 0.171 for the unsuccessful cluster, which shows that ABS has a higher accuracy than statistical analysis in this case. The agent-based method can not only model co-evolutions between these two types of cultural capitals such as knowledge and artistic values, but also virtual factors such as the education effect. Further, it is possible for the agent-based model to develop if-then conditional analysis by inverse simulation.

🌐 Summary and Conclusions

6.1

In this paper, following our previous work on civil service examinations in imperial China, we extended our agent-based history simulator and applied it to investigate women's role in a Chinese history family line, which continued to produce successful candidates over a period of five hundred years. For more rigorous results, we have utilized the real-coded GA through a grid oriented genetic algorithm framework to implement the simulation model, which expressed the family line network and the personal profile data as an adjacency matrix and as an attribution matrix, respectively. This sets the real profile data as an objective function.

From intensive experiments, we have demonstrated the roles of mothers and aunts focusing on the norms of the reciprocal relationship. Women are important to keep family norms although this had not been clearly shown because their roles were not properly recorded, but it was implicit in the historical records. The conclusions are as follows: (1) the combined influence of the father, uncle, mother and the aunt has important significance in maintaining a successful family norm, and (2) a particular role of the aunt to pass in on as well.

6.2

The main contribution of this work is that we discussed the marriage system and the women's role from the reciprocal viewpoints of family system in passing on the cultural capitals to the descendants. From a wife-giver to wife-taker perspective, the cultural capital passes on to the next generation from maternal father to daughter and from mother (daughter) to son. This indicates a cultural transmission from a wife-giver to a wife-taker family. On the other hand, the cultural capital in aunt's married family can also be transmitted from a wife-taker to a wife-giver family. This finding indicates that such a norm system can help rebuild the family fortunes when there is a marriage with girls from "good families"(wife-taker) or girls married to "good families"(wife-giver).

6.3

Theories about cultural reproduction tend to express that it is almost impossible for ordinary people to overcome their current rules of ideologies. However, the reproduction process of societies and their cultures is ever-changing. The mechanisms of social and cultural reproduction are never complete and are always faced with partially realized elements of opposition (Giroux 2001). Cultural elements of opposition will always emerge and will implicitly complement the rules of ideologies (Willis 1977). Through historical examination of the systems discussed in this paper, it was found that the system was ever changing, because of the critics and reviews repeated in each era. On one hand, the errors between simulation results and historical facts can be caused by elements of opposition against the reproduction of the rules of ideologies. However, on the other hand, the results of the analysis in this paper suggest that the effects of cultural reproduction are definitely strong in the historical flow. This indicates that today's society is also strongly affected by the cultural reproduction processes.

6.4

Our future work are 1) to apply our methods to another set of family line data in various countries in order to investigate the differences of cultural influential effects over history, and 2) to bridge conventional historical studies to agent-based modelling methodology.

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