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Preliminary Research on an Agent-Based Modeling and Simulation in Demographic Study

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Abstract. In this paper, an 'agent-based' approach to demographic research is introduced. The agent-based demographic simulation is expected to provide a more open-endedmodeling framework. While microsimulations are widely used in demographic studies, it lacks prescriptive capabilities of analyzing micro-interactions among individuals and environs. The presented agent-based demographic model is expected to provide a dynamic solution for demographic research which is difficult in microsimulations.

Keyword: Agent based modeling, data-driven modeling, demographic simulation, social microsimulation

1 Background

Predicting population changes with respect to human societal issues has been regarded as a challenging task due to the complexity of cross-societal interactions in reality. Thus, most demographic research has been simply focusing on phenomenological aspects of population changes as seen in statistics. To investigate the population dynamics and explain the uncertainties in more effective ways, the use of agent-based modeling and simulation has been suggested in social studies to cope with complex systems [1, 2].

As the most popular solution to analyze a complete set of population data, social microsimulation has been developed and widely used all over the world. The social microsimulation is a method which aims at modeling society as a group of individuals. In the model, each individual micro model can experience a sequence of events which a person may have such as birth, study, work and death. The fundamental components of a typical data-driven microsimulation model are summed up as shown in Fig.1 [3].

But microsimulation still has fatal limitations in its ability to mimic real societal changes and the resulting phenomena. The behaviors in the micro model are typically defined by transition probabilities with data driven parameters. Its transition probability lacks evolutionary dynamics because it comes from past demographic statistics statistical [4]. In the case of a real system, it is not true that all events happen in a sequence [5].

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In contrast, while the agent-based modeling seems similar to the microsimulation in that it is also an individual-level modeling approach, the agent-based approach is verydifferent in that it emphasizes "the interaction between individuals, with the main attribute of each individual being the operating characteristics (behavioral rules), which evolve stochastically over time in response to the success or failure of interactions with other individuals."[4]However, ABDMs are still at infant level due to the insufficient expertise gained. It has therefore not been used not to estimate dynamics in a system but to grasp insight in the system. Rather, the combined model with ABDMs and MSMs are increasingly developed so as to reflect more realistic factors in the proposed model [6].

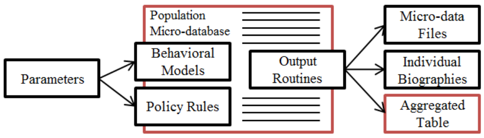

Fig.1. Fundamental components of a typical data-driven microsimulation model[3]

4 Modeling Framework

The main objectives of the research are summarized as follows: 1) provide a base design of agent-based simulation framework for demographic simulation with scalability and flexibility, and 2) Verify the proposed model with currently available data sets (Korean demographic data).

To represent Korean society, the initial agents are generated from the Korean census data in 1990[7]. The Korean census data gives individual parameters such as age and the relationship within a household. The initial agent has same sex, age, marital status and kinship with the corresponding personal data. The size of the initial population in the model is about 100,000.The entire Korean population size in 1990 is approximately 42.9 million. So, the scaling factor is 429 and one agent represents 429 people in the real world. The region of each agent is defined according to the Korean regional distribution in 1990[7]. But the specific position is randomly distributed in the region. The agent in the model is to be born, give birth, find a mate, get marriage, get divorced, and die. Some of the lifetime events follow demographic transition probabilities and others follow predefined rules. The behaviors following *transition probability*areas shown in Table 1.

Prob(behavior of 'k'|(sex of 'g'& age of 'x')) = (the population of the behavioral status of 'k' under 'g' and 'x')/(the total pop of 'g' and 'x') **(1)**

Korean marital status lifetable gives initial population and the number of transitions from the initial population according to age and gender. The transition probability is obtained from formula (1). The numerator and denominator aregiven by Korean marital status lifetable.

The transition condition at the stage ofdeath is relatively simple. However, the marital statusis more complicated as it is defined asfourdifferent states; never married, currently married, divorced, and widowed. All the transitionsa part from becoming widowed happen by following the state transition probabilities from demographic data. The transition *widowed* will happen when a spouse dies because this model is closed and the married people should be connected. By the same token, 'find a mate' exists as a sub-state in'currently married' to match and link a married couple. Anagentunder the 'find a mate' state is matched with other agents who have four preconditions to be a mate-able agentas follows:

1. *Same region : He/she should live in the same region with the partner*
2. *'find a mate' state : He/she is also in the 'find a mate' state*
3. *Different gender : He/she should be of a different gender tothe partner*
4. *Not kinship : He/she should not sharethe kinship of partner*

Table 1. Behaviors following transition probability and corresponding source

Behavior	Source	Note
Marital status transition	Marital status life table in 2000 [7]	The transition to the widowed isn't included.
Mortality		The aged over 100 is regarded as the aged at 100.
Fertility	Korean ASFR [7]	-

The Korean age-specific fertility rate (ASFR)from 1990 to 2012 is directly applied to the model [7]. In the source, the fertility rate for the age group below 15 and over 49 isn't available. So, the fertility rate in the model for this group is set as 0. In each year, 7 fertility rates are available for the groups. Each group has 5 consecutive age levels. For example, the 15-19 group includes the members aged at 15 to 19 and the fertility for all members of the 15-19 group in 1990 is equally 0.004. The ASFR in 1991 is estimated as below formula becausethe ASFR in 1991 is missing.

$$ASFR1991 = \{(TFR1991 - TFR1990)*ASFR1990 + (TFR1992 - TFR1991)* ASFR1992\}/(TFR1992 - TFR1990) \quad (2)$$

In the formula (2), TFR means Korean total fertility rate and the following numbers mean the corresponding year. The source of TFR is the Korean Statistics [7].

A new born child becomes a new agent in the model and therefore has age, gender, region and kinship. The age is set as 0. The gender will be male or female with a 50% probability. The region and relationship is set based on the mother.

5 Simulation Results and Conclusion

The agent in the developed model is defined as having one specific status among all combinations. The total combination is 12,120 for both gender groups, 101 age groups, 15 regions and 4 marital states. Moreover, each person adjusts with his environment and goes over to another state.20 replications for each initial population are conducted in Anylogic 7.The computation time to run this basic agent based simulation is not proportional to an initial population size. As the initial population size is 10 times greater, the computation time increases by 30 times.

To see the model's accuracy in aggregate, the population dynamics of Korea and the simulated population are compared in Table 2.The number of iterations is 20 and the averages of the population size from 1990 to 2013 are obtained. The end date is set as 2013 because the Korean fertility rate is only available until 2012 and the population size is recorded at the start of each year.

Table 2. The population dynamics of the Korean population and the simulated population

Years	1990	1995	2000	2005	2010	2013
Actual change rate	1.000	1.052	1.097	1.123	1.153	1.171
Simulated change rate	1.000	1.070	1.127	1.162	1.181	1.191
Error in change rates	0.0%	1.8%	3.1%	3.9%	2.9%	1.9%

In this study, a basic agent-based demographic model which includes fertility, mortality, location and transitions in marital status is developed with currently available dataon Korean demographics. We confirm that the modeling approach is promising in that there are still many factors that can be implemented to create a more realistic human life cycle picture in a virtual space. In the implementation stage, most transitions in the current model are directly taken from existing demographic data.

However, the huge computational complexity of the agent-based approach should be a challenging issue in the demographic study. As an initial population of system increases or the complexity of a system is getting higher, the computation issue becomes more and more critical. In this regard, the HPC and distributed computing application to agent based modeling should be carefully considered as a future study.

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