The Ribbon of Love

Fuzzy-Ruled Agents in Artificial Societies

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Abstract

The paper brings two motivations to the theoretical explorations of social analysis. The first is to enrich the agent based computational sociology by incorporating the fuzzy set theory in to the computational modeling. This is conducted by showing the importance to include the fuzziness into artificial agent's considerations and her way acquiring and articulate information. This is continued with the second motives to bring the Darwinian sexual selection theory – as it has been developed broadly in evolutionary psychology – into the analysis of social system including cultural analysis and other broad aspects of sociological fields. The two was combined in one computational model construction showing the fuzziness of mating choice, and how to have computational tools to explain broad fields of social realms. The paper ends with some opened further computer program development.

Keywords: fuzzy set, agent-based model, artificial societies, social simulations, social theory, sexual selection.

...that love and pride and honesty,
were to be gained at too high a cost...
"Thirty Summers" – Cowboy Junkies

01. From Theoretical Fuzziness to the Fuzzy Love

To be honest, the long history of social sciences told us stories of theoretical debates that frequently trapped social researchers into (sometimes) seemingly vague statements, confusions, and hesitations between explanations and descriptions (Craib, 1992), while eventually in some particular researchers and writers vigorously participate in the "postmodernistic" polemics questioning signs and language (read: lingua) in the observations to social phenomena . Here, in some cases social sciences loose their positive values of scientific endeavors, while in return brought some tensions with their counterparts in natural sciences faculties (*cf.* Situngkir, 2003a).

It is obvious that there is comparatively quite big differences between the place of an observer and her observant in social sciences and the natural sciences. Subjectivity of an observing agent may just arouse in the similar manners with those appear in a social actor acting as the observant. Furthermore, since measurements in social system are relatively hard to be trusted as a chemist, for instance, trusted her measurements of the chemical reactions she is being observed, there is no guarantee that certain social theory for being universal in its nature (see interesting debates in Eve, *at. al.* (1997) and *cf.* Tilly, 2004). Most social theory seems to be spatio-temporal with high sensitivity to time and historical backgrounds surrounding it. Some notions about path-dependencies are realized to become the source of this problem (*cf.* Arthur, 2005). Here we can see some difficulties that may yield the debates in the construction of social theory, *i.e.*:

- The *lack of pre-definition* to certain terminologies for tight definitive boundaries will gain the risk of reducing many things in the observations and in return the fail to extract any explanations.
- The *isotropic subjectivity* that always haunted when any justification is made over certain phenomena and even regularities in patterns.
- The *lack of validity measures on any measurements* conducted.
- The *phenomena of path-dependence in any social phenomena* that syntactically complexify the observation and analysis of regularities as the nature of social system (including the social analysis) overwhelmed with the so-called positive feedback.

Those facts, in some manners has invigorates the contra to lots of quantitative methods in social sciences and systematically harden any tight analytical approach to certain phenomena. The presence of computational sociology admits new breakthroughs in the improvements of scientific methods and modeling with some expectations to overcome those particular problems (Macy & Willer, 2002). Simulations as a way to do experiments by capturing the social dynamics has a great celebration among recent social analysts (Gilbert & Troitzsch, 1999), or some called them computational social scientist. Some works on agent-based model and how it could deliver social scientist get back to the track for the betterment of understandings without even being trapped to those factors elaborated above (*cf.* Epstein & Axtell (1996), Axelrod (1998), and some notions on qualitative validations by Moss & Edmonds, 2005). Thus, this sense makes the computational sociology becomes a good alternative tool for social researchers to observe, analyze, and understand

the dynamics (micro-macro, macro-macro, macro-micro, and micro-micro) of the social system in our age (*cf.* Coleman, 1990).

Computational sociology does the experiments to investigate phenomena from certain generative mechanisms (Situngkir, 2004b) and this is brought by imitating the underlying dynamics of particular social processes (Küppers & Lenhard, 2005). Nonetheless, as we gaze to the nature of the social analysis some innovations has been done in the way to build social simulations and artificial societies. A way to preserve the nature of non-quantifiable things in social processes (that is micro-decisions) is the motive of the paper. One possible way to do this is by employing the fuzzy sets and notions in membership degrees as introduced by Zadeh (1965) for fuzzy sets can be treated as an interesting approximators to a lot of measurements (Kosko, 1994) and thus become a powerful tool to understand the embedded complexity in social life (*cf.* Situngkir, 2003b).

In conventional modeling technique, researcher frequently transforms any measurement from the observation to the well-defined boundaries of measurement, even though she realizes that the crisp boundaries do not always exactly reflect what she is measuring. However, the fuzzy set transforming the exact choice to the certain method of probability in order to have continuous form between boundaries. Parameters like social actor's preferences, willingness, happiness, wellness, and so on, are not always be able to be mapped on to two opposite boundaries. In our daily realms, those parameters are always fuzzy and it is a hard way to measure the exactness in order to have complete form of discrete boundaries (see discussions in Smithson & Verkuilen, 2006:4-17). Fuzzy set theory can be seen as a transformer of the discreteness of cases into the continuous one by using the set of probabilities (Zadeh, 1978). In some philosophical perspective, the fuzzy set theory, nonetheless, can be seen as a way to bridging the logics and the vague statements in the sense of probability (*cf.* Dale, 1980).

The fuzziness is almost everywhere in social agent's daily life. There is no way to measure how a person loves another person while none can reflect the romance someone is feeling into crisp boundaries. This is the background of the paper which is presenting an innovation of agent based modeling and the construction of artificial societies by incorporating fuzzy set theory while trying to understand evolutionary social phenomena of sexual selection, love, and romance. The latter is, however, a rare discussions in classical sociological theory despite its importance as basic notions in human cultural realms as discussed briefly in the next section.

02. Sexual Selection and the Building of Evolutionary Social Theories

The dynamics of human sexual selection is usually related to sociobiology and rarely are discussed in the sociological theories. This is probably because sociobiology frequently leans on the evolutionary theories while in other place, sociologist are probably too busy revealing the "ideology" of the theory of evolution and hardly grasping the importance of biology in human behavior (*cf.* van den Berghe, 1990). Nevertheless, sociological endeavors to social life widely accept that individual's behavior must be a kind of product of complex interactions among biological predispositions and the total physical and social environment.

However, there have been advanced works for the inquiries to human sexuality and social phenomena, e.g.: social constructionism and postmodernism theories (see the detailed discussions in Sanderson, 2003). The work of sociology relating to human sexuality is frequently laid on the observations and political advocacy to feminism, homosexual

emancipation, etc. (e.g.: Foucault (1978), Epstein (1994), Ingraham (1994)) while in the other hand, many human preferences can be regarded in the sense of dimorphism of sexual differences between male and female shaping the macro-properties of our daily society (*cf.* Symons, 1979). The works on some social (and sometimes sociological) phenomena related to sexual selection is eventually finding a warm place at recent field of the so-called evolutionary psychology (Buss (1995), Miller (2000), and Rommel (2002)).

However, sexual selection theory did not born in sociology but a sort of theory complimentary to the natural selection theory of Charles Darwin (1871). Thus, admittedly sociological work reading the social phenomena in the notions of sexual dimorphisms and the mechanisms of sexual selection in human societies would in one case to be one the door to the evolutionary social theories.

In the other hand, the work on computational sociology has also some notions on evolutionary thoughts regarding to the way idea living and replicating in society as reflected in preference to artifacts and cultural aspects of the society known as memetics (*cf.* Situngkir, 2004a). Here, the evolutionary theory terminologies are used to establish computational model for certain cultural aspects in the sense of recent Darwinian evolutionary theory of selfish gene as the term 'meme' (later defined to be the smallest element of information) by biologist, Richard Dawkins (1976). However, as later discussed in the last section of the paper, remarks founded on our observations of sexual selection in the terms of sociobiology meets the memetics should both establish a possible new adventure to the realm of the development to new sociological thinking on human culture and social living.

03. Fuzzy Case: Story of Love

Obviously, one does not need any scientific background to realize that human sexuality is much more complex relative to other animals on earth. There is a very tight connection between sex and culture in human societies. Sex is not as simple as reproduction, for there are many constraints relating to sexual properties: the social norms and habits, sexual preference relating to love, emotional feelings (e.g.: jealousy, romance), finance and wealth, and even sometimes political aspects. Thus, in particular views sexual preferences are fuzzy in its nature, and hence a good example on how we can incorporate the fuzzy set theory to the computational social analysis.

Imagine we have an artificial society which agents are represented as grids in a ribbon: the end grid is connected to the beginning one. Throughout the computational rounds, the ribbon gets bigger and bigger. Each grid in the ribbon has 16 neighbors on both the left and the right side. Thus, as we have N_{ref} agents the N_{ref}-th agent has 16 neighbors counted from the beginning of the ribbon world and vice versa, the first agent has 8 neighbors from the end. As neighbors are representing the social network of each agent, agent can only have reference to change her sexual qualities of attraction within the total 32 neighbors. However, an agent may find her mate with bigger social network since it is plausible to assume that a social agent could found her mate in the social network of a friend N_{mate}. Thus, $N_{ref} < N_{mate}$. This inequality is considered to fulfill the nature of the bounded social agent with modification reflecting reality to the social realms.

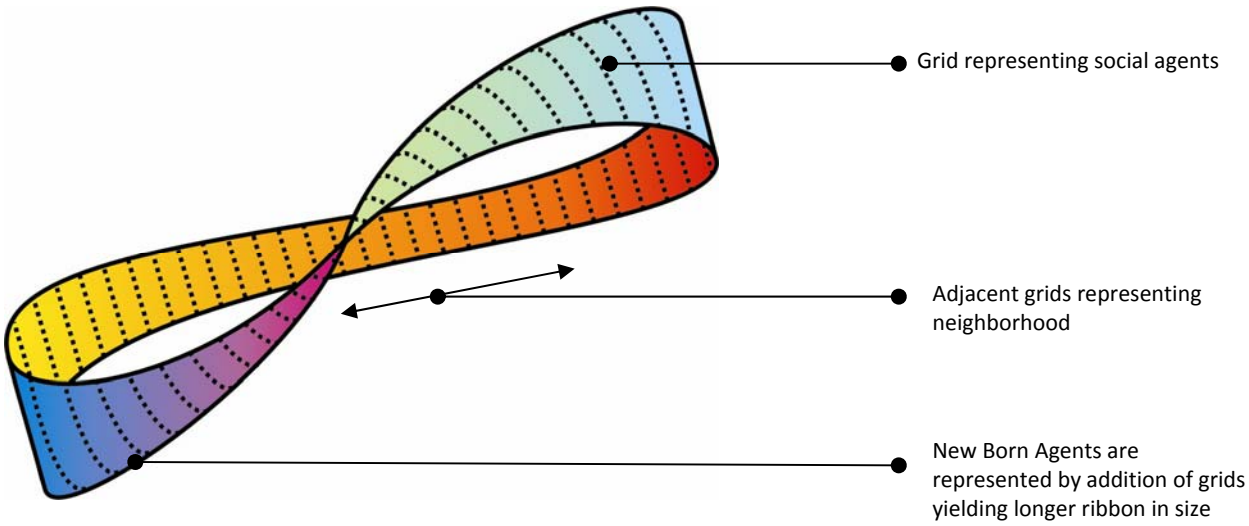

Figure 1. The Ribbon of Love

In our model, the possibility of an agent becomes homosexual is zero, thus agent decide to mate only with those with different sexual identities. The life expectancy of each agent is fixed: as soon as agents reach certain age ($u_i(t) = \tau$) they die and the spouse becomes available to mate with other agents since one of the assumptions of our model is that the world is monogamous. In our model, to love somebody is to marry him and takes the chances to have offspring that would share the traits of her and the husband. Those are assumptions of the model while the way agent chooses the opposite sex to become the spouse is different between a male chooses the female and the female chooses the male. This notion is laid upon empirical findings in the discourse of evolutionary psychology as elaborated in surveys conducted by Buss (1986) and Shackelford, *et. al.* (2005).

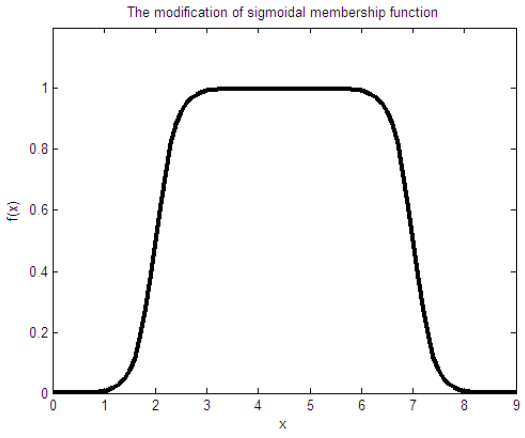

Figure 2. The Membership Function

How a male chooses a female and vice versa is where we combined the fuzzy set theory and the computational agent based model. First of first, agents are provided with

some qualities that is used to attract the opposite sex mate-wannabe. Reading the works of evolutionary psychology (Buss, 1993) we can extract some of those qualities as physical appearances ($Q_p^i(t)$) of agent i that is related to physical fitness and mental performance ($Q_m^i(t)$) related to intelligence ($q_{m(intelligence)}^i(t)$), fidelity ($q_{m(\ fidelity)}^i(t)$), and other psychological and mental personal performance regarding to sexual attractiveness ($q_{m(p)}^i(t)$). The latter can be regarded to some properties e.g.: speaking ability, sense of humor, tenderness, kindness, and probably religiosity. For the sake of simplicity in our model, we relate the intelligence to the wealth and finance of agents while whether an agent is faithful to the spouse or not it can be regarded to be an independent variable as logical consequence of our monogamous primitive term. Nonetheless, even we employ the fidelity index, as soon as an agent is matched with her mate; she cannot flirt nor do any infidel behavior towards other male, and vice versa.

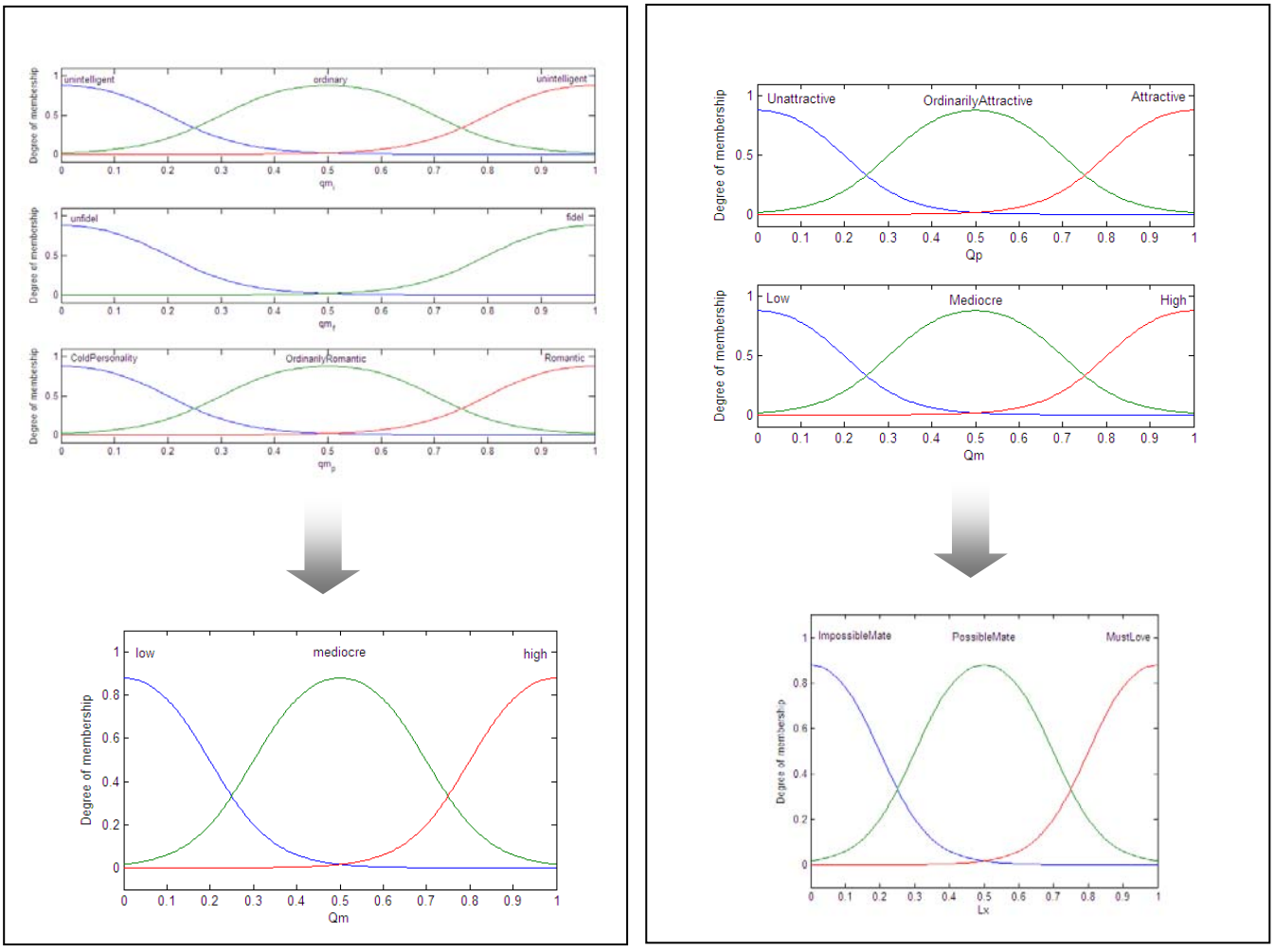

Figure 3. The fuzzy rule to the mental performance (*left*) and the way physical and mental qualities forming the preference index (*right*).

The micro-properties of each agent are defined in the Mamdani fuzzy rule with inputs and outputs using the modification to the standard sigmoidal membership functions. Compared to the classical set, we can write the crisp membership of properties in

$$Z = \{x \mid x \leq \delta\} \tag{1}$$

while regarding to Zadeh (1978), the probability function transform the crisp and discrete boundaries into smooth and continuous membership degrees, as in the exemplification of equation (1), we can write,

$$Z = \{x, f_z(x) \mid x \in X\} \tag{2}$$

where the membership function $f_Z(x)$ maps $\exists x \to \{(0,1)\}$.

In the discussion of the applications of fuzzy set theory, we recognize tons of membership functions with varying purposes and the necessities of the representations, e.g.: the piecewise linear function, Gaussian distribution functions, sigmoid curve, quadratic and cubic polynomial curve (Smithson & Verkuilen, 2006). Further technically speaking, membership function used here is made up by using the one composed of the difference between two sigmoidal membership functions. We choose this type of membership function for its simplicity and popularity while it has smooth transition from lower to higher probability as the fuzzified variables grows. The sigmoidal membership function depends upon two parameters, say α and β and is given by

$$f_{sigmoid}(x, \alpha, \beta) = \frac{1}{1 + \exp(\alpha(\beta - x))} \tag{3}$$

Thus, the membership function used here depends on four parameters α_1, β_1, α_2, β_2, and is the difference between two of the sigmoidal functions; see figure 2. Thus, we write,

$$f(x) = f_{sigmoid}(x, \alpha_1, \beta_1) - f_{sigmoid}(x, \alpha_2, \beta_2) \tag{4}$$

This membership function, $f(x)$, is applied to each variables used in the fuzzification of our heterogeneous agents. The Mamdani Rules are applied to defuzzify the value of $Q_m^i(t)$ IF…THEN rules which each elements are related with *OR* operator (by means of maximization of probability),

$$|Q_m^i(t)|_{mamdani} \equiv q^i_{m(intelligence)}(t) \textbf{ AND } q^i_{m(\,fidelity)}(t) \textbf{ AND } q^i_{m(\,p)}(t) \tag{5}$$

We must understand that the rules applied in the case a male towards a female, $|Q_m^{i:m\to f}(t)|_{mamdani}$, will be different with the one a female towards a male, $|Q_m^{i:f\to m}(t)|_{mamdani}$. Males relatively emphasize the importance of female physical appearance since from the evolutionary paradigm beauty represents fertility and health males crave about in their reproductive life,

$$Q_p^{i:f\to m} > Q_p^{i:m\to f} \tag{6}$$

while female attracted more to the mental states, be it the intelligence factors or other psychological and personal appearances,

$$q^{i:m\to f}_{m(intelligence)} > q^{i:f\to m}_{m(intelligence)} \tag{7}$$

$$q^{i:m\to f}_{m(p)} > q^{i:f\to m}_{m(p)} \tag{8}$$

since from the evolutionary psychological point of view, mating in the courtship would be a way to access the highest quality of wealth and protection provided by males. These properties can also be related to the craving of females to match with the ones with ability of the highest intelligence and personal/psychological traits the ability to nurture the offspring they might have in the marriage.

The Mamdani Rules are also applied to defuzzify the tendency to be loved by the opposite sex (we might be tempted to denote it as love index representing the possibility to be loved by average opposite sex), as

$$L^i_x(t) \equiv Q^i_m(t) \ \textbf{\textit{AND}} \ Q^i_p(t) \tag{9}$$

The fuzzification and the Mamdani Rules applied in (5) and (6) are visualized in figure 3.

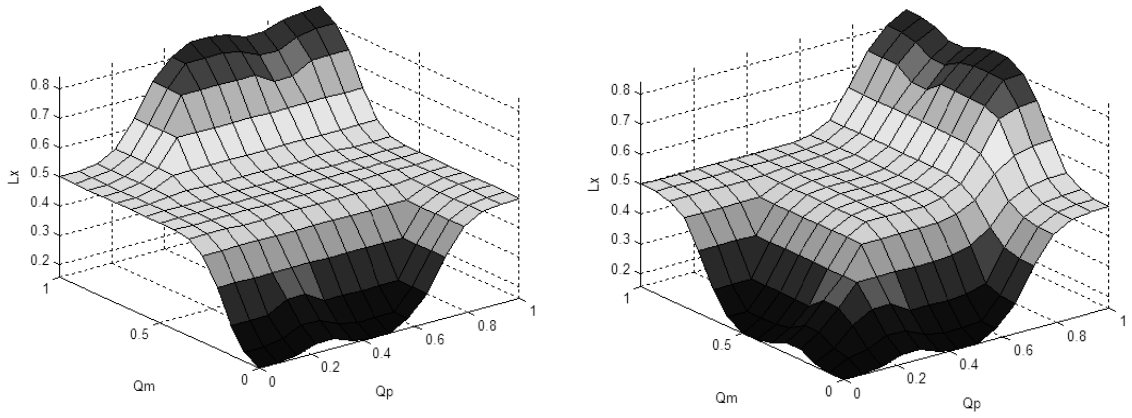

Figure 4. The rule of love index of $L^{i:m\to f}_x$ (*left)* contrasted to the one $L^{i:f\to m}_x$ (*right*)

The variables representing the quality of each micro-property are changing over our computational time: technically, the iteration in the simulation. Other properties, such as wealth or financial capability can upgrade dynamically the personal qualities higher agent's status in the court. In our simple computational model, regarding the social economic theory of Durlauf & Young (2001), we can roughly saying that myopically rational agents would have their financial and economic growth concerning the neighbors'. Thus, the individual agent economic growth will always be related to the economic and financial average of the neighbors. Mathematically, we can roughly say that the wealth growth of an agent, $w^i(t)$, will be proportional to the average of her N_{ref}-sized neighbors wealth with certain probabilities,

$$w^i(t+1) - w^i(t) \cong \delta\left\{\frac{1}{k}\sum_j^{N_{ref}} w^j(t)\right\} \qquad (10)$$

Where $\delta = \begin{cases} 1, & \text{with probability} = 1 - p \\ r_w, & \text{with probability} = p/2 \\ -r_w, & \text{with probability} = p/2 \end{cases}$

and r_w as the predefined wealth changing constant.

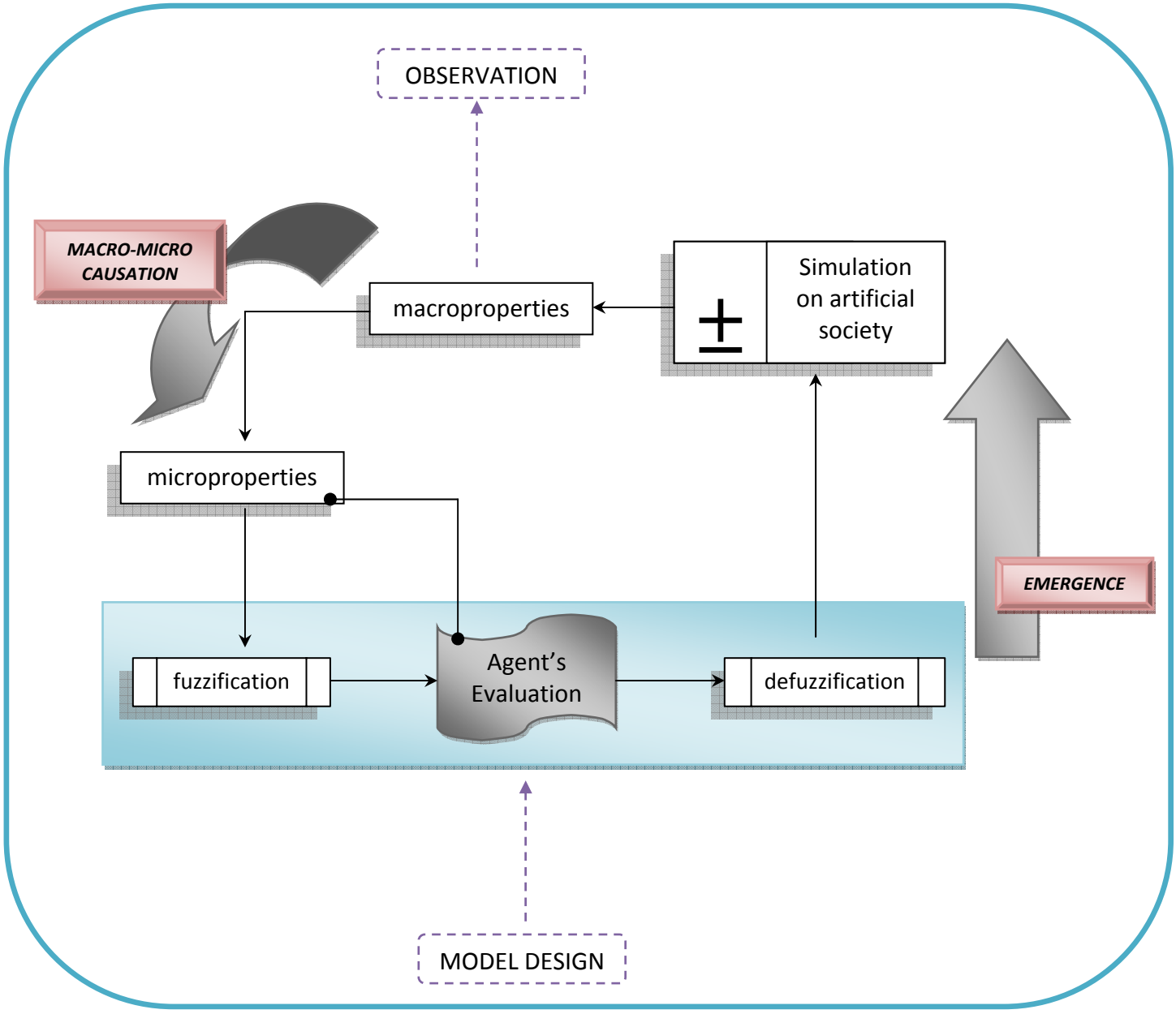

Figure 5. The flow diagram from the step of designing the model to the observing the macro-properties in the Fuzzy Ruled Artificial Society with the perspective of macro-micro causation and the micro-macro emergence.

Furthermore, the changes in the wealth would also bring the changing in the quality of sexual attractiveness: a wealthy agent will more likely to have better beauty management while also have wider opportunities on improving her intelligence. We can write this down as,

$$q^i_{m(intelligence)}(t+1) \cong \begin{cases} q^i_{m(intelligence)}(t), & \text{with probability } = 1-p \\ (1+r_q)q^i_{m(intelligence)}(t), & \text{with probability } = p/2 \\ (1-r_q)q^i_{m(intelligence)}(t), & \text{with probability } = p/2 \end{cases} \quad (11)$$

and the similar one

$$Q^i_p(t+1) \cong \begin{cases} Q^i_p(t), & \text{with probability } = 1-p \\ (1+r_q)Q^i_p(t), & \text{with probability } = p/2 \\ (1-r_q)Q^i_p(t), & \text{with probability } = p/2 \end{cases} \quad (12)$$

where r_q is the change rate of the individual sexual quality.

However, as it has been noted by the findings in evolutionary psychology (Hill & Reeve, 2004), in some cases of female, the sexual quality that would attract male decreases over time in a constant factor of $r_{q:f\to m}$ as she ages reach certain values,

$$Q^{i:f\to m}_p(t+1) \cong (1-r_{q:f\to m})Q^{i:f\to m}_p(t) \quad (13)$$

and

$$q^{i:f\to m}_{m(p)}(t+1) \cong (1-r_{q:f\to m})q^{i:f\to m}_{m(p)}(t) \quad (14)$$

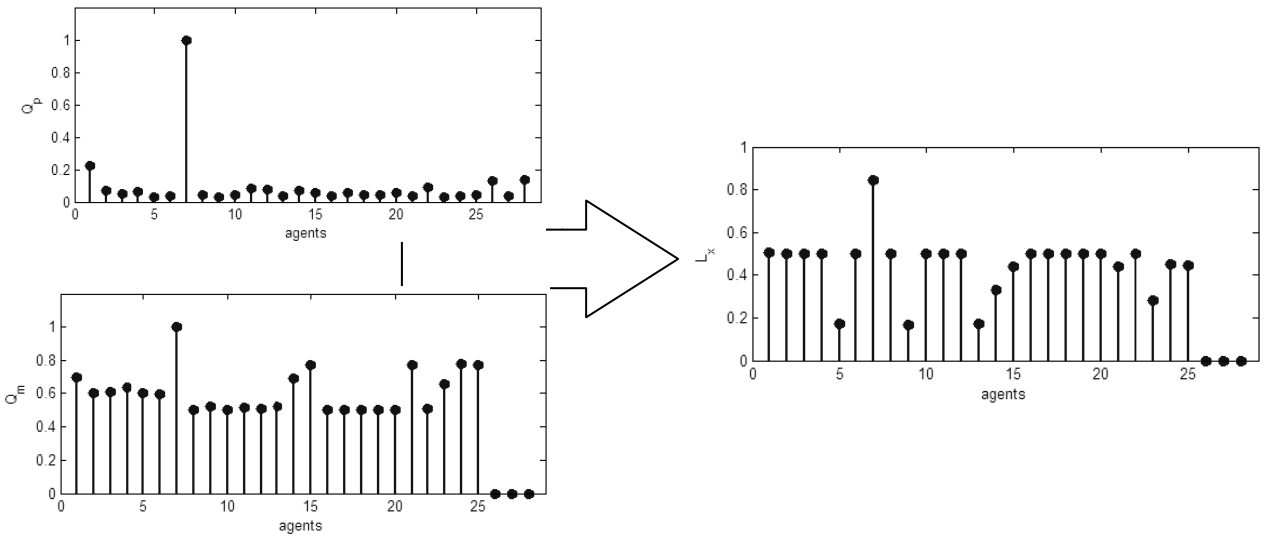

Figure 6. The fuzzy rules evaluating each agent's loveable index.

Finally, the matching process thus can occur as each agent evaluates the opposite sex agents in her neighborhood and sorting them in a kind row with the highest love index, $L_x^i(t)$, in the first row and can be regarded to be proposed. Then, each agent evaluates the proposals merges to her and if match, both may getting married. Furthermore, any marriage couple might results the offspring: limited one on each computational time (iteration) with certain probability. The newborn offspring thus is represented by the addition of one more grid in the ribbon of which properties shared the ones representing both parents. Nonetheless, the number newborn offspring eventually must be balanced by the number of the dead agents. As soon as an agent goes beyond the predefined life expectation index, the respective agent dies and is omitted from the ribbon.

04. Discussions & Open Further Works

From this point, now we have an experiment to do some experiments in social analysis in the consideration of the distinction between sexual preferences between male and female in human societies. One interesting micro-properties to be observed is as depicted in figure 4. Here, the rule of the defuzzification of males and females qualities related to attraction from the respective opposite presents the distinctions between different sexes. This figure shows the empirical findings shown in the inequality (6), (7), and (8) in the way of fuzzy rules. The asymmetry between female and male is confirmed in our fuzzy inference system. This is interesting since the vagueness of the inequalities is now ready to be defuzzified for our computational (numerical) simulations. It seems to be simple but the transformation from crisp boundaries into continuous ones is in fact raising the complexity of the system in its microstates.

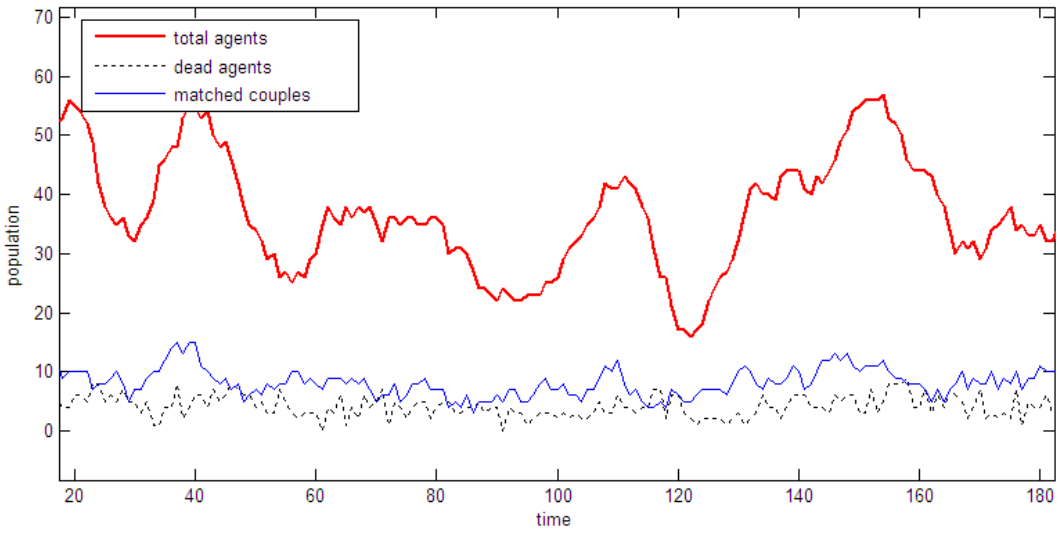

Figure 7. The macro-properties emerged from the heterogeneous fuzzy-ruled interacting agents.

In advance, as it has been a common understanding in the approaches of computational sociology incorporating the agent based models, the micro-properties are going to used to emerge macro-properties as generative data for the use of analytical observation (*cf.* Situngkir (2004b), Epstein & Axtell (1994)). The flow diagram of the usability

of fuzzy-ruled agent based model is summarized in figure 5. Apparently, the only difference of the standard agent-based model is the method of fuzzification and defuzzification incorporated in agent's evaluation. As the design of the artificial society was constructed by using the fuzzy rules, the modification of the system is left on the "qualitative" fuzzy measures or micro-rules.

The macro-properties are still having causative relations with the microstates in the numerical sense, but agents acquainted them as qualities and particular probability measures. The computational model discussed in the previous section shows this obviously. Artificial social agents recognized and decide information mostly by using feelings and even sometimes "irrational" decision-makings when folks talk about the long-life partners, lovers, husbands and wives. However, it is actually clear, certain parameterizations (that can be represented in crisp numerical values) are present in those emotional and psychological stuff. Thus, the artificial agents are given opportunities to process information in a similar manner human agents do in every day life.

Figure 7 depicted three variables from the macro view of the completely artificial system as emerged from the interacting heterogeneous fuzzy-ruled agents. The fuzzy-based decision system of agents eventually yielded the generative quantitative data for further analysis of the system. The big picture from this discussion is that the seemingly continuous micro-properties (if not qualitative and flexible) then in aggregation yield a set of data to be approached by using statistical if not rigorously quantitative methods. It is the heart motive of the paper and would be the qualitative proposition depicting our daily social life, especially as we talk about love and romance.

05. Concluding Remarks

We outlined the theoretical background of the main property in the computational sociology approaches including agent-based model in social analysis as and the artificial society. This is brought by contrasting certain (classical) sociological approaches and the evolutionary notions on social processes. The natures of the human individual preferences are heterogeneous without any crisp boundaries (discrete choices) but by mapping the crisp boundaries to the (continuous) probability of values in the term of membership function and fuzzy ruled agents.

Sexual selection is considered play important thing in the interspecies evolution. While interspecies evolution and competitive processes within are rarely considered important in conventional sociological works, the advancements of evolutionary psychology researches has shown its interesting ability to explain particular social and sociological features. This is somewhat a challenge for the future of sociological analysis under the umbrella of greater analytical scope of general social science to incorporating many social and cultural phenomena in the terms of evolutionary paradigms. Since sexual selection holds the major role in intra-species competition, the comprehensive computational approaches are unavoidably needed.

We have built a computational model showing the fuzzy-ruled heterogeneous agents to be simulated to dynamically use their artificial cognition to decide whom to mate with and what to do in order to have the best mate by upgrading respective sexual qualities as perceived by the opposite sex. The simulation results shows that the built model opens many possible further experiments that one day could be verified with more and more empirical data. This should have become an interesting feature of computational sociology

as two scientific disciplines can present productive innovations for the heart of computational sociology is interdisciplinary discourses.

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