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Title
Dual Mode Behaviors in Telecommunications Associated with Dual Topological Characteristics

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Short Title
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Abstract

The very large hub property may not be applicable beyond the part of human behaviors bounded by the digital divide or media-gender gap. To provide a more balanced view for studying telecommunication behaviors, a dynamic cognitive model is proposed. The model indicates that there are two major relationally (topologically) distinct types of human behaviors: closed and open. Closed behaviors strongly depend on entities in the environment with limited dimensional effects to oneself, which generate discrete type relations of experiences. Open behaviors weakly depend on the environment with unlimited dimensional effects on oneself, which generate continuous-type relations of experiences. Based on this model, a wide variety of dual characteristics in modern telecommunications are informally explained. The media gender gaps are explained by a gender model. The long-term profile of web use activity decay of home users is explained as the typical characteristic of closed behaviors.

Keywords

Networking graph, Telecommunications, Cognitive behavioral model, Topological dynamics, Gender-gap, Traffic biases, Long-term dependency, Scale-free network, Reversibility, Duality, Asymmetric motion, Chaotic itinerancy, Phenomenology

1. Introduction

It has been emphasized that many behavioral networks (graphs) are associated with very large hubs [1], where the number of alternate paths is usually quite small. This emphasis seems appropriate for some limited behaviors but may lack a balanced view for understanding human behaviors. In fact, telecommunication markets consist of, at least, two evidently different types of traffic. One type is strongly biased among users. In other words, a small percentage of users generate a large share of the traffic volume. The other type of traffic is weakly biased among users. This bias-gap may have been recognized for a long time and attracted more attentions recently in connection with broadband businesses [2]. For example, long-distance telephone calls, Internet access from PCs, and broadband services for both fixed-line and mobile access are said to be strongly biased traffic. Short-distance telephone calls, mobile phone calls, and short-messages on mobile phone are said to be weakly biased traffic.

The very large hub property may be the characteristic of telecommunications with strongly biased traffic but it is not a characteristic of those with weakly biased traffic. In fact, the numbers of nodes with larger number of links in behavioral networks with weakly biased traffic seem to decay more rapidly than those with strongly biased traffic (see Section 2.11). On the other hand, telecommunications with strongly biased traffic seem to be accompanied by digital divide (e.g., [3]) and have limited prevalence whereas those with weakly biased traffic prevail over most people. Thus the very large hub property may not be applicable beyond the part of human behaviors bounded by such a divide. Moreover, we should not overlook the fact that the bias-gaps in telecommunications are associated with media gender-gaps (e.g., [4, 5, 6, 7, 8]).

In order to understand behaviors with more balanced views, especially for telecommunications, this paper proposes a dynamic cognitive behavioral model. This model provides a balanced view and enables us to explain how these bias-gaps emerge with distinctly different behavioral networks. The model indicates that there are two major relationally (topologically) distinct types of human behaviors: *closed* and *open*. Behaviors of the closed type strongly depend on the environment with limited dimensional effects on oneself, which generate discrete-type relations (topology) in his/her experience. Stronger dependency on the environment means a stronger adaptation load, which implies stronger traffic biases among the users. Behaviors of the open type weakly depend on the environment with unlimited dimensional effects to oneself, which generate continuous type relations (topology, c.f. Lewin [9, 10]) in his/her experience. Weaker dependency on the environment means weaker adaptation load, which implies weaker traffic biases among the users.

Based on this model, a wide variety of dual characteristics found in modern telecommunications can be informally explained. Here, the gender gaps are explained by a gender model in terms of these two types of behaviors. In addition, the long-term activity decay of web use activity [11] is explained as the stronger activity bias along the time axis, which is a typical dynamical characteristic of closed type behaviors.

The model consists of three levels: 1) the interaction level (short-term microscopic level) covers short-term interactions of a person with the environment, 2) the person level (long-term microscopic level) covers long-term behavior of a person, and 3) the social level (long-term macroscopic level) covers long-term behaviors of many people. The essence of this model is the interaction level. The personal level is given by a long-run of the interaction level. The social level is then given by combining personal level models with topological and dynamical consistency. The essential hypothesis of the interaction level is also simple: one type, called closed, goes to the environment, whereas the other type, called open, brings an entity from the environment. Interactions of one type can be reversed ([12]) to the other type. It is naturally derived that these two types are associated with dual (anti-symmetric) characteristics. Among the characteristics are the sensed boundary at the interface (environment/sensor), dimensionality of the sensing (lower/higher), adaptation and dependency of the interaction on the environment (strong/weak), interaction intensity (higher/lower), and relation type of effects (closed/open) (see Section 3).

The interaction level model shares the view with Merleau-Ponty's two-hand experiment [12], where the duality of characteristics seems not to be given in the literature. Gibson's affordance [13] may correspond to the effects of closed interactions and may not be appropriate for those of open interactions because the effects can hardly be considered as the attributes or properties of the environmental entities. Dynamics in the relations/topology of experiences may share the basic idea of Lewin's theory [9, 10]. On the other hand, we can draw the person-level model from the two distinct long-term properties of topological dynamics. One is "chaotic itinerancy" [14] for considering lower-dimensional dynamics and the other is "asymmetric-motion" [15] for higher dimensional dynamics.

This paper is organized as follows. Section 2 discusses modern telecommunications from various viewpoints not limited to traffic. It is noted that modern telecommunications consist of two major domains represented by mobile phones and Internet/PC. These two domains show binary opposite (or dual) characteristics in various macroscopic aspects such as market evolution, user demographics, fees, system, industry, and traffic. Some of these dual characteristics are correlated with gender differences in the use of media and computer technologies. Section 3 presents the model. Section 4 explains and discusses the characteristics of behavioral phenomena in terms of the model. Section 5 concludes this paper.

2. Dual Characteristics in Modern Telecommunications

Recently, telecommunications have evolved extensively, and now they are very complex. Despite the complexity, it is not difficult to recognize that there are two major fields in modern telecommunications as shown in Fig. 1. In this figure, Internet/PC prevalences [16] are highly varried with respect to the ordering by the mobile phone prevalences [16], which indicates that Internet/PC and mobile phone uses are fairly independent behaviors. One field comprises mobile phone communications, which can be seen as having evolved from the ordinary telephony. The other comprises communications mediated by the Internet, intranets/LANs, and PCs, which can be seen as having evolved from the downsizing and globalization of computer networks.

Figure 1. Worldwide Prevalence of Mobile Phones, PCs, and Internet (Source: ITU [16]).

It should be emphasized that these two fields show dual characteristics, which are binary opposite characteristics in various aspects as listed in Table 1. It is often said that modern communication media usage exhibits gender differences, e.g., [4, 5, 6, 7, 8] such as feminine and masculine characteristics (as in [17]). These dual characteristics are consistent with the gender differences but seem too wide to be explained in terms of gender alone. These various dual characteristics suggest

that more basic properties of an individual underlie the gender differences.

Table 1. Dual Characteristics of Modern Telecommunications

2.1 Market Evolution

Internet/PC communications arrived with a bang, but since then it has taken a long time to become pervasive throughout each country. Namely, in 1994, when Netscape Navigator was released, the growth rate of Internet hosts in the world increased from 0.9 million per year to 2.7 million per year [18, 19]. In 1996, approximately 40% of companies with more than 300 employees began to subscribe to Internet access services in Japan (p. 90 in [20]). Nowadays, subscribers are still rapidly increasing throughout the world. However, in most of the OECD countries, less than 40% of inhabitants subscribed to fixed Internet connections in 2001 (p. 121 in [21]). On the other hand, mobile phones may have begun to prevail silently in countries, since there were no significant events that characterized the start of their prevalence. Subsequently, they seemed to have become pervasive rapidly throughout many countries. In fact, in many countries, more than 50% of habitants subscribed to mobile phone services in 2002 as shown in Fig. 1. The revenue of Internet/PC communications has not been stable. This can be seen in the unstable revenues of leased lines (p. 79 in [21]). In addition, the growth rate of web sites dropped sharply from the period of 1991-2000 to that of 2000-2001 due to the dot-com meltdown, which caused bubble-like collapses of Internet backbone companies [22]. On the other hand, the revenue of mobile communications has increased steadily (p. 74 in [21]).

2.2 Social Types of Major Users

Organizations such as business enterprises, companies, research institutes, universities, governments, and so on strongly accept and actively use Internet/PCs, while they still use cellular phones in a limited way. For example, 95.8% of Japanese companies with more than 300 employees subscribed to the Internet in 2000 [20]. Over 40% of US employees age 25 and over accessed the Internet in the workplace in 2003, while nearly 30% of them talked less on the telephone than before they began to use the Internet at work in 2001 [23]. On the other hand, mobile phones are strongly accepted and usually used for personal matters, while Internet/PCs have limited personal use. In fact, there is a big gap between the subscriptions to mobile phones and to the Internet as seen in Fig. 1, which indicates that the needs of mobile phone personal communications are much stronger than those of Internet accesses. Lenhart et al. [24] reported that more than 40% of US adults were still non-users of the Internet in 2003, whereas 17% of non-users were once users. The number of "drop-outs" increased from 2000 [24], which is typical digital-divide behaviors (see also [3]).

2.3 Fees

Internet/PC communications have become very cheap, in contrast to mobile phone communications. In seven OECD countries, unlimited Internet access by Digital Subscriber Lines (DSLs) was available for less than 50 USD per month in 2002 (p. 176 in [21]). On the other hand, in the average OECD country, a family of 4 average users of cellular phones paid 140 USD or more per month in 2001 (p. 164 in [21]).

2.4 Age Characteristics of Users

Reflecting the importance of Internet/PCs in businesses, active users are not limited to young people. According to the survey by Fox et al. [25] conducted in 2000, 51% of 50--54-year-old US people access the Internet, whereas 56% of all US people access it. Compared with the early stage, the users have shifted to elderly people. Figure 2 shows age compositions of Internet users from 1995 to 2003 in Japan. In this figure, young adults of 20-29 years old no longer comprise the largest part. This implies that the aging of young users cannot fully explain the shift to elderly users.

Figure 2. Age Shift of Internet Users in Japan (Source: CSJ [26]).

On the other hand, young people are quite active in using mobile phones. Surveys report that high percentages of teenagers have their own mobile phones: 79% in German (2003) [27], 70% in Israel (2002) [28], 69% in Japan (2002) [29], and 40% in US (2003) [30]. Although these percentages are not the highest among the age groups, teenagers seem to be the most active among them. This is because most teenagers spend a large portion of their very limited amount of disposable income. In fact, mobile phone use has introduced a new and permanent expense for them. To measure this impact, Dentsu Communication Institute [31] introduced the "Engel-like coefficient for mobile phone use." This coefficient is defined as (P1/P2)×100%, where

P1: Personal expenses for mobile phone use,
P2: Personal expenses for all information-related products and services.

Table 2 presents this ratio for each age group of Japanese in 2002. This table shows a significant impact on personal finances, which shows that teenagers feel a significant need to use mobile phones.

Table 2. Engel-like Coefficients for Mobile Phone Use (Source: [31]).

2.5 Gender Difference

Although no significant gender difference can be seen in recent prevalence in some countries, opposite gender biases in the diffusions of Internet/PC and mobile phones can be seen in most countries. On average, males have been more active in using computers than females, as many studies have found [32, 33, 34, 35, 36, 37, 38, 39, 40]. As a result, in 1998, GVU [41] reported that 66.4% of respondents to a WWW user survey were male, which was clearly larger than the portion of females (33.6%). Nowadays, gender lags have been reduced but they still remain (Fig.3).

Figure 3. Gender Lags in Internet/PC Use (Source: ITU [16]).

On the other hand, it is well known that females use phones more actively than males. Women have been quite active in using fixed-line phones, e.g., [4, 5, 6, 42]. Before the prevalence of mobile phones, the pager's prevalence among high school girls was more than double that among high school boys in Japan (1997) [43]. The total usage of mobile phones and fixed-line phones by women is much higher than that of men [44] in Norway (1998). Adolescent girls (13-17 year olds) send short texts more frequently and call for a longer time per day with mobile phones than males. An exception can be seen for the rate of young adult men [45] in calling via mobile phone excluding the sending of short text messages. Young adult men call for longer per day via mobile phone than young adult women call do. This is explained by the fact that a young adult man is somewhat nomadic. That is, he tends to call from a café in the period between graduating from high school and establishing a family and working life [45]. In fact, it can be seen through the surveys [46] and the studies [45, 47] that young adult men may make mobile phone calls to both women and men whereas young adult women make calls more to women (female friends) than to men. These calling behaviors of young adult men are perhaps based on the fact that young women already have phones so they can receive men's private calls. Thus, young adult women seem to be at the center of mobile phone communications, surrounded by young adult men.

2.6 Main Contents

With an Internet-connected PC, we usually search, collect, and exchange the information necessary or useful for our business, research, studies, education, and hobbies. We also play games with PCs and sometimes play them over Internet. According to the survey of Horrigan and Raine [48] conducted in March 2001, Internet/PC communications in the US become more serious as people access the Internet more frequently to help them do their jobs not only from the workplace but also

from home, as more people read web pages to get healthcare information, news, financial information, and product information, and as people send email to their family in order to advise them and to express worries rather than to maintain social relationships. In this survey, 67% of US users said Internet helps them get involved in things outside their community, compared with only 9% who said it helps them get involved in things close to home. On the other hand, active users of mobile phones make calls and send short texts for private communications with partners, families, and friends [45, 47].

2.7 Volume of Contents

One can easily see that Internet sites provide us with large documents including better quality pictures, photos, some graphic programs, and some movies. The larger sizes of these contents can be seen in our interactions, where we scroll windows frequently to read them. These Internet sites often have a deep hierarchies organized for details. E-mails sent over Internet/PC usually contain many sentences. Of course, there are applications with light content volume like instant messaging. However, these light-content applications and services come later and seem to be a limited part rather than the mainstream way of using Internet/PCs. On the other hand, most telephone and mobile phone communications are calls completed within a few minutes. The volume of information exchanged in calls and short-messages is quite limited compared with that obtained from Internet surfing. In other words, with PC/Internet, users generally desire higher quality and heavier volume of content with wider bandwidth, whereas most mobile phone users are satisfied with a limited voice quality, short messages, light games, short ring-tone music and so on.

2.8 System Structure

Internet/PC systems and networks have evolved by interconnecting open systems, e.g. [49], and benefiting from the existing infrastructures without contributing to them. So they can be regarded as parasites. Moreover, a number of open technologies have played very important roles in the evolution of the Internet/PC field. Among typical well-known examples are the open source strategy of UNIX, the open consortium of Ethernet [50], and the open architecture of PC/AT (DOS/V) computers, e.g., [51]. On the other hand, mobile phone networks have been constructed mainly on their own infrastructures, with huge investments. Most parts of the system, such as networks, terminals, services, and contracts with users, have been kept closed, (especially in Japan). For example, users cannot change and extend the functions of their own mobile phone terminals as they can with their PCs. Thus, you cannot send a picture in your phone directly to the phone of a friend just in front of you but must send it via the operator's network and pay a charge, at least up to 2003.

2.9 Industrial Structure

Companies and enterprises providing hardware or software components, services, and contents for the Internet/PC field are said to be non-hierarchical (called heterarchical in [52]). Namely, each actor possibly leads the market evolution of Internet/PC based on its core competence. Moreover, the boundary between users and suppliers is not clear because an active user in the Internet/PC field sometimes becomes a supplier of contents, software, or services. On the other hand, in the field of mobile phone telecommunications, companies are ordered in the hierarchy with mega-carriers (big operators) at the root level. Namely, the mega-carriers determine what kind of products and services are to be supplied to the market (at least in Japan, where mobile phone market is quite active). Users are users forever even in the case of very active users of mobile phones.

2.10 Traffic Characteristics

Internet/PC traffic is both temporally and spatially strongly biased whereas mobile phone traffic is both temporally and spatially weakly biased. Here, spatial biases mean the biases among users, where weak (strong) bias of Internet/PC (mobile phone) is well-known (e.g., [2]). As for the

temporal biases, there was a basic finding in the 90's in the network engineering of Internet/PC that traffic of these networks exhibits long-term dependency [53]. The ordinary statistical models of telecommunication traffic used in designing systems have been essentially based on short-term dependency such as Poisson processes, e.g., [54]. On the other hand, mobile phone traffic, like classic telephony, exhibits rather shorter-term dependency, e.g., [55, 56], than Internet/PC. As shown in [57, 58], long-term dependency means a lower generation rate of entropy, whereas short-term dependency means a higher generation rate of entropy.

2.11 Networking Graph Characteristics

The very large hubs of the behavioral graphs seem characteristic of Internet/PC but not of mobile phones. (Here, the broadband service of mobile phones is not considered because this service seems atypical of most mobile-phone-based behavior.) In fact, as shown in Table 3, the decaying exponent γ of networking graph data [59, 60], defined by

$$\mathrm{Nr}\{v \in V \mid l(v) = k\} \propto k^{-\gamma} + o(k^{-\gamma}),$$

is clearly larger for mobile phones than for Internet/PC, where V denotes the graph's node set, $l(v)$ denotes the number of links connected to node v, and Nr indicates the cardinal number of the set on the right side. In the table, a node is a user. A link is given to a pair of nodes if messages are sent in both directions of the pair during a measured period. In [60], γ =2.2, but this is a mistake in computation and the correct value is γ=3.2 (private communication with the first author).

Table 3. Decaying Exponents of Networking Graphs.

3. Dynamic Cognitive Model

Let us present a dynamic cognitive behavioral model. The essence is reversible dual actions (Fig. 4), which describe the primitive behavior of a person with the environment in the short-term. Cognitive processes and other levels are drawn from this basic model.

3.1 Interaction Level

Reversible dual actions: There are two distinct basic types in the actions of a person with the environment as shown in Fig. 4: One type (*A* in Fig. 4) is to act toward the environment whereas the other type (*B*) is to bring an entity in the environment to the person's proximity. These two types of actions can be switched, as shown in Fig. 4, each other by reversing the way while this switching causes a discontinuity of the effect as discussed in [12].

Figure 4. Reversible Dual Interactions of a Person with the Environment

The reversible dual actions cause the following dual cognitive processes with anti-symmetric characteristics:

Closed cognitive process: In an action toward the environment, the person tries to generate an interaction using a limited part of him/herself but with a strong contact to an entity in the environment. This action causes, if possible, low dimensional strong-intensity of effects on the person, which is an experience with narrow relations to the past experiences. Through this interaction, the person perceives the contacted surface of the entity but does not perceive the contacted surface of the person. This interaction, including its effects, depends strongly on the entity in the environment but depends weakly on the others in the environment (It uses limited channels).

The low-dimensional effects on the person, the narrow relations to the past experiences, and the division between the sensing boundary (the contacted surface of the person) and the sensed boundary (the contacted surface of an environmental entity) mean that this cognitive process is closed.

Open cognitive process: In a "bring" action, the person uses a wide-open area of her/himself but with light contacts. This action causes, if possible, higher-dimensional light intensity of effects on the person, which is an experience with wide relations to the past experiences. Through this interaction, the person perceives the contacted surface of the person but does not perceive the contacted surface of the entity. This interaction, including its effects, depends widely on the person and her/his proximity. In her/his neighborhood, there is no clear boundary dividing the environment side and her/his own side (lack of Cartesian boundary).

The unlimited dimensional effects on the person, the wide relations to the experience, and the sharing of the sensing and sensed boundaries (both of them are the contacted area of the person) mean that this cognitive process is open.

The reversibility shares the view with Merleau-Ponty [12], where these anti-symmetric cognitive characteristics seem not to be given in the literature. Gibson's affordance [13] may correspond to the effects of closed interactions but may not play effective roles for those of open interactions. This is because the effects of open interactions can hardly be considered as the attributes or properties of the environmental entities.

3.2 Personal Level

Let us describe a long-term behavior of a person by a long-run of the short-term model 3.1 given above. Here, behaviors are (informally) described in terms of topological properties of experiences. In fact, behaviors are usually experienced by the person whereas experiences are associated with topological properties such as continuous/discontinuous, related/non-related, distant/near, and so on (c.f. [9, 10]).

Dual mental modes: The experiences of the dual interactions cause dual major mental modes, where the person's behaviors are biased to a fixed type of interactions.

Closed mode (Fig. 5(a)): The person moves around at least mentally and acts toward the environment. For starting a closed interaction, the individual may spend time preparing both herself/himself and an entity of the environment so that the individual succeeds in generating a new closed interaction. The timing to start the interaction can be delayed, but an interruption after the start may collapse the closed interaction. The activity of the closed interaction decays over time and then the individual exits from the interaction. After exiting from a closed interaction, the individual restarts moving around and then acts toward the environment repeatedly. A new closed interaction is separated from the experiences of other interactions, whereas the interactions with similar environmental entities are perceived to be the same because of the strong dependency on the entities. Thus closed interactions can be seen to generate closed sites in the individual's experiences and copies of them can be generated in different environments as far as the entity to interact with is perceived to be the same. However, in a re-visited site, the interaction is no more heavily active than the time when the site was firstly generated. Thus, closed sites can survive, but they age over time, and then the individual may go far away from a specific region of the closed sites.

Open mode (Fig. 5(b)): In the open mode, the person (at least mentally) sits down at a place where unfamiliar entities in the environment are in distant areas. The individual selects a preferable entity, which is not dangerous to interact (tamed), in the environment and brings it to her/his proximity and then immediately starts an open higher-dimensional interaction with the entity. The interaction may finish soon but the brought entity and the experience are not entirely deleted and part of them is kept in the proximity. The individual restarts the process of selecting another entity and brings it to her/his proximity and then generates the next open interaction. Repetitions of these bringing interactions pile up parts of these entities and experiences, which expand her/his neighborhood of proximities. Because an open interaction strongly depends on the neighborhood of proximities (in the experiences) evolved by preceding open interactions, open interactions are usually mutually and widely correlated with past experiences. Thus, experiences of interactions in this mode can be seen as a large open continuum generated in the expanding neighborhood of proximities. The dynamics

of this open continuum is very complex. Interactions are continuously generated and consumed. Associated with this, preferable entities placed at the boundary of the neighborhood and their generated mental effects float on the continuum to the deep center gradually.

Figure 5. Dual Modes of Personal Behaviors

It should be noted that the topological property of these long-term dynamics are consistent with the computational/formal studies of topological dynamics. In fact, the closed-mode behaviors are similar to the chaotic itinerancy [14] of lower-dimensional dynamics, whereas the open-mode behaviors are also similar to the asymmetric motion [15] of higher-dimensional dynamics.

3.3 Social Level

Three types of inter-personal behaviors: One type of interaction is based on the closed-mode behaviors, where closed sites are exchanged or they compete to occur. The second type of interaction is based on the open-mode behaviors, where open interactions of individuals share the same environmental entities for interactions. The third type of interaction is between closed and open mode behaviors, where the environmental entities are transferred from the closed-mode behaviors to the open-mode behaviors.

History dependence: Closed site may be exchanged or competed with strong activities among the individuals even with different histories. On the other hand, deep interactions among open-mode behaviors need some similarity among the open neighborhoods of the individuals. In the transfers of tamed environmental entities from closed-mode behaviors to open-mode behaviors, the prevalence of entities in the closed-mode behaviors does not imply the similar prevalence in the open-mode behaviors.

Dual adaptations: There are a number of the separate domains of inter-open mode where open-mode behaviors interact with each other. A connected domain where closed-mode behaviors interact with each other surrounds these open-mode domains (see Fig 6). The closed-mode domain interfaces with the outside, where new environmental factors emerge. The closed-mode domain expands by generating new closed sites through the actions toward the environments, which plays a progressive role adaptation. The open-mode domain expands because piled-up preferable tamed entities extend the open neighborhoods, which play a conservative role in adaptation.

Figure 6. Adaptation to the Environment of the Society of Individuals Based on Interactions of Closed- and Open-Mode Behaviors.

4. Explanations and Discussions of Characteristics in Modern Telecommunications

In order to explain the characteristics of behavioral graphs (networks), let us first derive basic topological and dynamical properties of relations among the elements in the experience.

4. 1 Basic Topological and Dynamical Properties of the Behavioral Graph Associated with the Dual Mode Behaviors

A cognitive interaction causes a relation among the experiences. The cognitive interactions described in Fig. 4 shows that closed (open) type interactions cause closed-limited and strong (open-wide and light) dependence on the past experiences. This implies the local topology of relations. That is, in the neighborhood of an experience, there are the smaller (larger) numbers of discrete and persistent (continuous and variable) relations among experiences, see Fig 7.

Figure 7. Topological and Dynamical Properties of the Relations of Experienced Elements in the Dual Modes.

In this figure, a two dimensional region expresses a relation of experiences (points in the regions) caused by an interaction. Placements of regions represent further relations and variability among

the relations. The neighborhood near a relation is illustrated. This figure describes local areas of Fig 5.

Let us assume that behavioral graphs essentially represent the relations among experiences. Then, the model asserts the following local structure of the behavioral graphs. Here, locality means the neighborhood of the path or the subset of nodes that is associated with a relation of experiences.

"Proposition" The behavioral graphs of closed (open) mode behaviors are closed and discrete (open and continuous) in the sense that most of the paths have smaller (larger) numbers of neighboring or alternate paths in the graph.

"Corollary" The behavioral graphs of closed (open) mode have limited (large) numbers of medium sized-hubs (local bases).

The following figures illustrate some typical behavioral graphs associated with closed- and open-mode behaviors respectively. In (a), there are a small number of global bases (the nodes that are linked to most of the nodes) and few of local bases (nodes that are linked to a moderate number of the nodes). A path (which signifies an interaction) has a small number of neighboring paths (closed property) and a small number of alternative paths. In (b), there are a small number of local bases and no global bases. A path has a large number of neighboring paths (open property) or alternative paths.

Figure 8. Topological Characteristics of Behavioral Graphs Associated with the Dual Mode.

This figure is produced from a questionnaire survey for young people in class rooms on telecommunication uses, related activities, and interests (conducted in 1998 when young people's communications changed dramatically). Each graph is constructed from a subset S of the respondents. The nodes are the items to select. An arrow is given from the item i to the item j if most of the respondents who select j also select i for the respondents in S. The graph (a) represents selection behavior of boys whereas the graph (b) represents those of girls in a school.

Fig. 8 seems to show structures beyond the local neighborhood of a path. That is, a stronger bias to the global bases can be seen in (a) and a uniformity in (b). The bias gap, which is a non-local property, follows from the local topology. In fact, generally speaking, closed discrete local topology of relations (paths) implies that strongly biased relations are generic (i.e., most of the possible configuration of relations are strongly biased). Alternatively, open continuous local topology implies that weakly biased relations are generic. This implies the following non-local characteristics of the relations.

"**Proposition**" The relations and their evolutions among the experiences of closed (open) mode behaviors are strongly (weakly) biased.

4. 2 Activity Profiles of the Dual Mode Behaviors

The bias-gap property of relational evolution given above implies the following temporal activity bias-gap.

"Proposition" The activity of closed behaviors is temporally strongly biased whereas that of open mode behaviors is weakly biased.

Moreover, the model implies that the activity of closed mode behaviors tends to decay over the time if the person's area for search has been explored whereas open mode behaviors usually find new effects with the large continuum of experience. Then the typical activity profiles can be given by Fig. 9, where (a) ((b)) is activity of closed (open) mode behaviors in long term.

Figure 9. Typical Long-Term Activity Profiles of Dual Modes.

The activity profile of (a) was reported by Kraut et al. [11] as web-use in a home, especially for young or male users. The model indicates that the activity profile of mobile phone uses, especially by female users, is (b) as explained below. However, there are no similar reports for mobile phone uses, so this is a conjecture of this paper.

4. 3 Explanations of Dual Characteristics of Modern Telecommunications

Market Evolution: Activities of closed interactions mediated by a new tool may follow the profile (a) in Fig. 9 in their nature, whereas those of open-mode interactions mediated by a new tool may follow the profile (b) drawn in this figure if the new tool expands the open neighborhood of proximities. This profile may explain the nature of the Internet/PC market. In fact, the rapidly increasing activities seen in the early stage tend to let companies overestimate future growth whereas the long-term slow-down of the activity follows, which may have caused the difficulties [61] for the companies serving Internet backbones. On the other hand, the tool mediating open mode does not seem so significant for the user at the early stage but the activity is kept or continuously increasing in a long-term. Thus, the open-mode behaviors explain the strong nature of the mobile phone market, on which mobile mega carriers have been founded in Japan. On the other hand, slowly increasing activities in the early stage tend to let companies underestimate future growth, which may have skewed mobile phone services in the U.S. [62].

Social Type of Major Users: People acting in enterprises are usually closed mode behaviors whereas individuals are based at the places like the home where open-mode behaviors are major. In fact, the environmental entities supplied by these organizations to the consumers are developed by incorporating new environmental factors beyond the boundary of the ordinary world. These are actions toward the environment. On the other hand, an individual's life is usually based on the familiar places, goods, experiences and relationships, whereas familiar interactions affect the wide-open experiences of the individual.

Payments: A central reason of the payment difference may be the nature of needs described as activity profiles in Fig. 8. Other reasons are open/closed properties of the systems and the industrial structures described in the table, which is explained below. This is because the openness of the systems, including user-supplier contracts as well as those of the industry, usually reduces the prices of services.

Age Characteristics of Users: From the macroscopic viewpoints, closed-mode behaviors play such progressive roles as organizations play. These are managed by elder people whereas open-mode behaviors play such conservative roles as individuals play in their familiar places where young people rapidly increase their familiarities to the surrounding environment rather than elderly people do. From the microscopic viewpoints, closed mode may get old, whereas open mode may not. In fact, a closed interaction with a new entity in the environment generates a new closed site, which is strongly dependent on the entity. This generated closed site can survive because a similar entity in the environment causes a similar interaction as long as the basic skills for the interaction are kept. However, this closed site gets old because revisits of the site cause a lower level of activities than the first visit caused. In other words, revisits of generated closed sites do not need such strong activities as needed before. Thus, the more one gains closed interactions the better she/he wanders the closed sites. On the other hand, the open mode may not prefer to get old. Namely, open-mode interactions are driven by incoming brought entities. Because interactions are open and higher-dimensional, incoming entities usually cause new interactions and new affects extensively. These affects continuously and extensively consume the individual's activity, which seem more appropriate for young people than elderly people.

Gender gap: This is the consequence of applying the following gender model.

Gender Model On average, the open modes of females are more developed than the closed modes, whereas the closed modes of males are more developed than the open modes.

Such properties of the open mode as the female gender bias, the non-aging property, and the familiarity of contents imply that the communications among young females with their friends are quite active. This explains the higher activity of mobile phone use among adolescent females. Furthermore, the higher activity of young adult males in mobile phone use can be seen as the collaborations of the dual modes for expanding the open-mode domains. In short, a female probably sends short text messages in order to bring the male's phone calls to her proximity. Let us explain this briefly. First of all, Fig. 4 as well as the two-hand experiment shows that closed mode and open mode can interact directly with higher activities. The gender model and the dual adaptations in Section 3.3 implies that males would like to moving around physically and frequently to make mobile phone calls from remote places for closed-open communications with females as well as for closed-closed communications with other males. This explains the nomadic behaviors of young adult males and the anti-symmetric call originations between males and females. Moreover, males use voice communications much more frequently, whereas females use short text messaging much more frequently [45, 63]. An ordinary explanation is the difference in personal expenses between them. In addition to this reasoning, the originations of phone calls often act toward the environment because they might interrupt the behaviors of friends. The affects of this interruption on the friend and possible refusals of the call may introduce slight unrest if the user is in the open mode, where damages can be easily caused in general. This suggests that females use short text messaging more frequently.

Main Contents: Information useful in business, hobbies, and studies are usually supplied as documents of a certain volume that include special knowledge. One should read these documents carefully to understand the special knowledge, and then she/he puts it into practice. These careful readings, understandings, and practices can be seen as closed-mode behaviors because they are based on logical structures constructed on separated and narrow steps as seen in the long-term closed-mode behaviors (Fig. 5 (a)). Moreover, in such fields as businesses, hobbies, and studies, progresses are quite important. This is the role of closed-mode behaviors as in the dual adaptations in Section 3.3. As described in the historical dependence in Section 3.3, an arbitrary pair of individuals may communicate in their closed modes as long as they can agree on the transfer of a closed site. This arbitrariness does not hold for the open-mode communications. The bringing actions of the entities exchanged in the communications should cause open and wide affects on these two open neighborhoods. Thus, these two individuals are familiar with each other. Typical examples of familiar relations are between lovers, among the members of a family, among friends, among neighbors, among colleagues, and so on.

Contents Volume: Closed mode interactions strongly depend on entities in the environment. The activity of the closed interaction is much stronger if the transferred or copied entities are accurate for the limited-dimensional contact interface of the actions toward them. In telecommunications, this accuracy needs a large amount of information to be transferred. In addition, because closed sites in the closed modes can survive for some time, contents for the closed modes can be stacked up. Moreover, each closed site does not so much depend on each individual's history, and thus contents for the closed modes are possibly shared widely as in Section 3.3. Thus, contents for closed modes become rich. On the other hand, the local area consists of familiar entities and is very compatible with the neighborhood of the open mode as above. Communications specific to the local area seem to be usually in the open modes for the people living in the area. Thus, the contents for the closed modes may be rich but limited to those for global use.

As for the open modes, interactions are not so much dependent on the entities brought from the surrounding area of the open neighborhood (Section 3.2). Thus, contents for open modes are not necessarily large-sized. In addition, because an open interaction follows immediately after the bringing action (Section 3.1), delayed responses to the bringing actions usually lose the opportunities of interactions. Moreover, the non-aging nature of the open mode as mentioned above does not

allow the contents to be stacked for some time. Thus, light contents are much easier to be used in open-mode communications than large-sized ones. It should be noted that this argument does not mean that open-mode behaviors do not interact with high-bandwidth contents. For example, video of familiar people may cause open interactions.

System Structure: In the closed mode, there are many various closed sites (Section 3.2). Each closed site strongly depends on the environmental entities for interacting (Section 3.1). Functions supplied by an information communication system provide such entities. Consider a system supporting closed mode very well. This system should provide unlimited variety of these entities, which implies an unlimited variety of functions. On the other hand, the closed interaction may occupy a function for a long time (Section 3.1). This occupation process is difficult to predict because of the discrete nature of the sites. Therefore, the processes of using functions are quite complex and difficult to predict for both the variety of functions and the times to start and to finish occupations of functions. Because of the uncertain wide variety of functions to be used in the closed mode, open structures are indispensable for this system. An action toward the environment can spend the time to prepare and to set up the functions with open interfaces so as to generate a closed interaction where separations of closed sites as in Fig. 5 (a) illustrate the consistency of closed interactions with the delays before their starts. Then functions for closed-mode interactions can be clarified and constructed when they are needed. This construction process of functions can be seen as if systems supporting closed sites were parasites of previously dedicated systems.

On the other hand, open interactions do not necessarily need a variety of functions. Consider a system mediating an open sub-continuum of the experiences of open interactions. This system should enable the user to bring entities continuously from the boundary to the wide-open area of proximities constituting the neighborhood (Section 3.2). Here, proximities include the brought entities and piled experiences of the past open interactions. In other words, the performance of the system can be measured by the amount of the environmental entities that are compatible with the open neighborhood and can be instantly and continuously brought and the extent of the area of the proximities to which these environmental entities can be brought. In telecommunications, consider the case when one wants to tell some interesting happening to a friend. This happening is the entity placed in the boundary, whereas the proximities are the experiences that the friend felt interesting. A good system for open-mode communications should enable the user to quickly send a message about any such event to the appropriate proximities of the appropriate friends. Thus, the system does not need to supply a wide-variety of functions but needs to instantly access appropriate places in wide-open regions of users. This system need not have open functions and can be closed. Moreover, closed systems help the suppliers to control and optimize a system's behaviors for quick and accurate accesses to the proximities. In addition, a closed system helps the suppliers to keep or gain the reward.

Industrial Structure: The industry developing systems can be heterarchical [52] and dynamic if these systems are open. At the same time, closed systems tend to make the industry hierarchical and static. Moreover, progress is often made by the actions toward the environment (the dual adaptations in Section 3.3). Because progress leads to supplying products and services, users of the systems for closed modes sometimes become suppliers by providing the closed sites generated by them. On the other hand, open-mode interactions consume entities in the environment by bring them and expanding the open neighborhood (Section 3.2). Open mode is suitable for consuming but not for developing new environmental entities (the dual adaptation in Section3.3). Moreover, because the system for open mode tends to be closed, users hardly ever become suppliers in the system.

Traffic Characteristics: For telecommunication systems, "traffic" of a user is the time series of holding times of network resources, which reflects the series of time intervals spent for interactions. Therefore, the characteristics of the traffic for each telecommunication domain must reflect that of interactions in corresponding behavioral mode. Thus these bias-gaps are consequence of the bias-gap propositions in Section 4.1 and 4.2, which are essentially derived from the local topological

structures. Practically, in the closed mode, once a user enters a closed site, she/he does not exit immediately as described in Section 3.2. Because a closed interaction strongly depends on the environmental entities with stronger effects to the user, the user tries to adapt to the environmental entities. This microscopic adaptation should continue during the closed interaction, which can be seen as the adaptation to this closed interaction. Therefore, the longer elapsed time in a closed site probably means the more adaptation to this interaction, which implies that the more time will probably be spent staying at the site. Thus, the temporal characteristic of the closed-mode behavior is at long-range dependence, which implies long-range dependence of Internet/PC telecommunication traffic. The bias-gaps among the users can be explained by the adaptation load gaps between the dual modes.

Networking Graph Characteristics: From the discussions above, Internet/PC mediates closed mode behaviors better than open mode behaviors whereas mobile phones mediate open mode behaviors better than closed mode behaviors. If this is valid, the shift of the decaying exponent follows from Propositions in Section 4.1.

5. Concluding Discussion

Let us note important future subjects and related topics. The topological characteristic of word network [64] seems quite consistent with the social level mode with the mappings from centric word uses to open type behaviors and from marginal word uses to closed type behaviors. The gender model in Section 4.3 may also explain sex-difference in cognitive skills [65] as well as the gender schema [17, 66]. Moreover, the model also seems consistent with the significant difference between maternal and paternal network graphs of DNA groupings [67] and the description of biological origin of sex [68]. On the other hand, the social level model (Section 3.3) can be considered as a non-equilibrium open system consistent with the 2^{nd} law of the thermo-dynamics, where the entropy generation rate seems lower near the boundary and higher in centric area. Moreover, the separated open-mode domains caused by the historical dependency in the social level model can be seen to represent the failure of the global village predicted by McLuhan [69] under the world-wide prevalence of Internet. Inter-national differences such as individualism and collectivism [70] may be represented in terms of the biases between the two modes.

These consistencies or relations to the wide-variety of behavioral phenomena may imply the view of behaviors provided by the reversible dual interactions (Section 3.1) plays basic roles in understanding complex (behavioral) systems.

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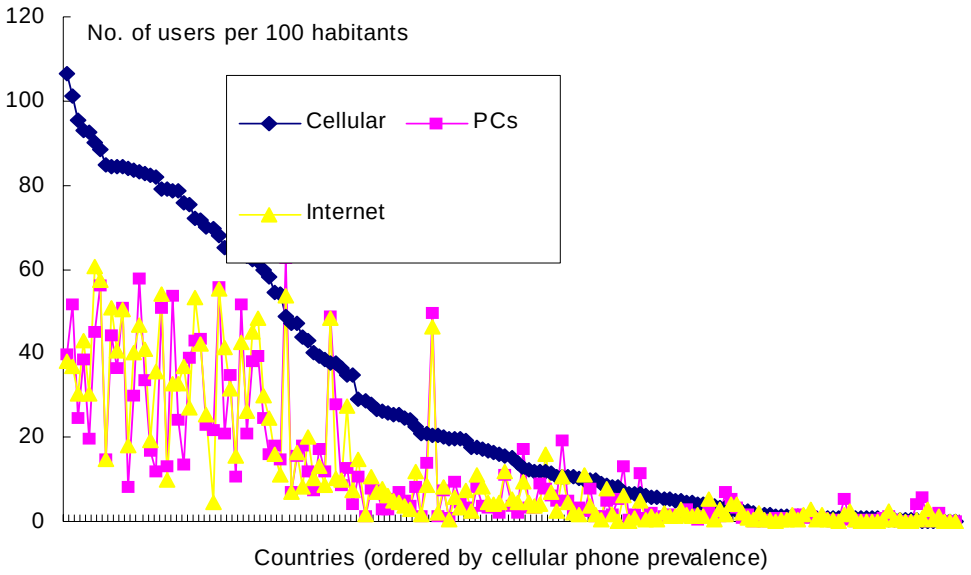


Figure 1. Worldwide Prevalence of Mobile Phones, PCs, and Internet (Source: ITU [16]).

Table 1. Dual Characteristics of Modern Telecommunications

	Internet/PC	Mobile phone
Market evolution	High-impact introduction Limited prevalence Some bubbles and burst cycles	Silent introduction Higher prevalence Steady revenue
Social type of major users	Organization	Individual
Fee	Cheap	Expensive
Age	Shift to elderly	The younger the stronger activity
Gender bias	Masculine	Feminine
Main contents	Information useful in business, hobby, study. Playing games. To use with the outside of the local community	Private communication with partner, family, and friends. To use within the local community
Contents volume	Rich	Light
System (Environment)	Wide variety of complex functions, “Parasite” to existing infra, Interconnections of open elements	Limited variety of simple functions, Huge investment for infra, Closed-ness of network, terminal, service, contracts with users, etc
Industry	Heterarchical and dynamic industry. Users sometimes become suppliers	Hierarchical and static industry. Users are users forever
Traffic	Strongly biased among users Long range dependence (Lower entropy generation)	Weakly biased among users Short range dependence (Higher entropy generation)
Networking Graph (Behavior)	The number of larger hubs decays slowly.	The number of larger hubs decays rapidly.

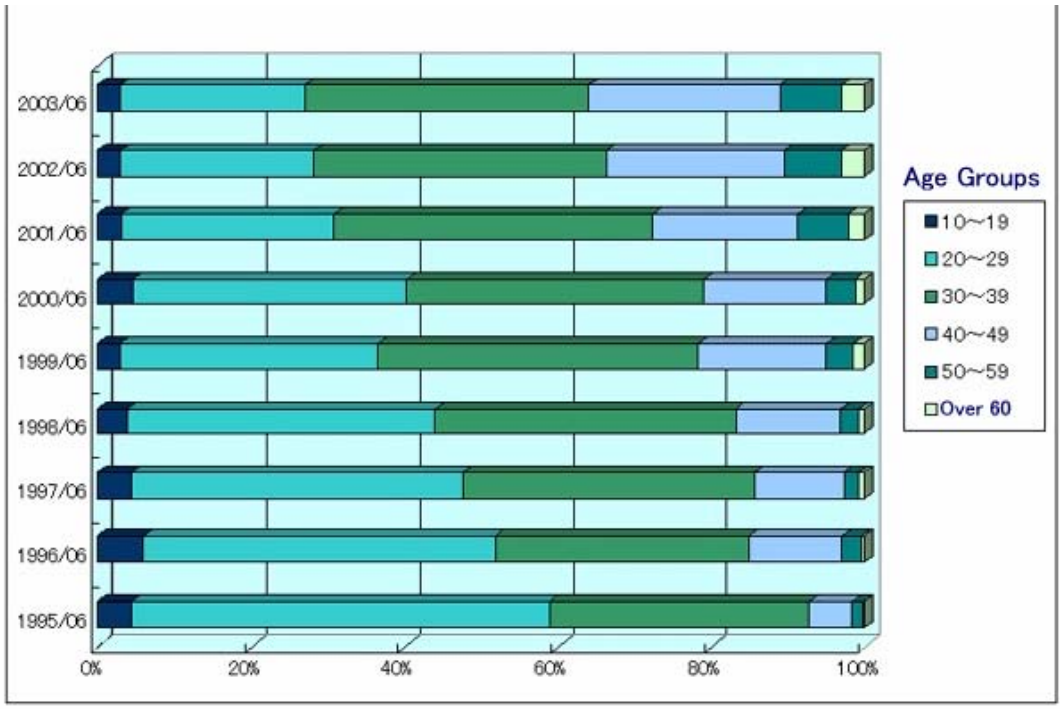


Figure 2 Age Shift of Internet Users in Japan (Source: CSJ [26]).

Table 2. Engel-like Coefficients for Mobile Phone Use (Source: [31]).

Gender \ Age	10-19	20-29	30-39	40-49	50-59
Male	84.3%	41.8%	17.9%	17.1%	14.0%
Female	71.1%	32.4%	21.7%	15.0%	20.0%

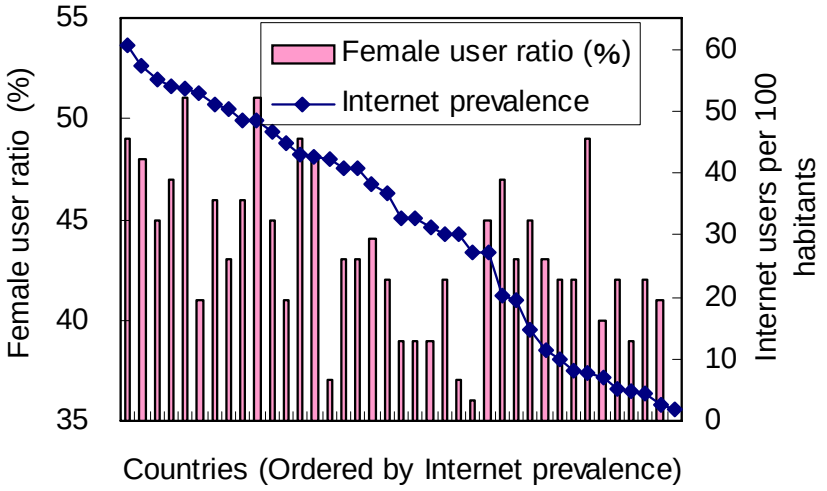


Figure 3. Gender Lags in Internet/PC Use (Source: ITU [2003a]).

Table 3. Decaying Exponents of Networking Graphs.

Service	Exponent (γ)	Reference
Internet/PC mail	1.8	Ebel et al. [59]
Mobile phone mail (i-mode)	3.2	Aida et al [60]

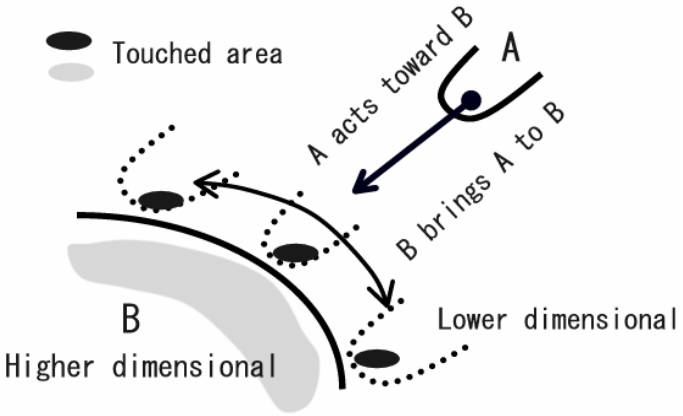
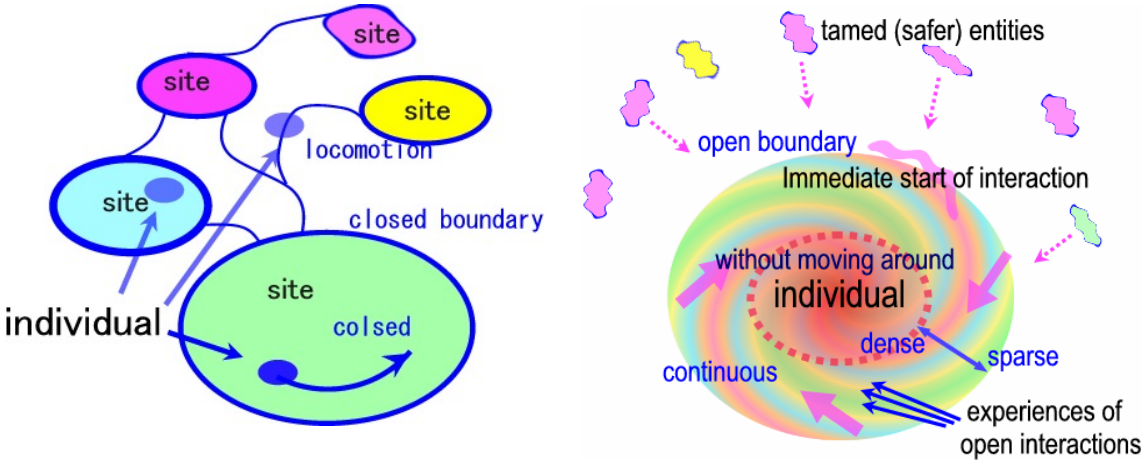


Figure 4. Reversible Dual Interactions of a Person with the Environment.



(a) Closed mode behaviors (b) Open mode behaviors

Figure 5. Dual Modes of Personal Behaviors.

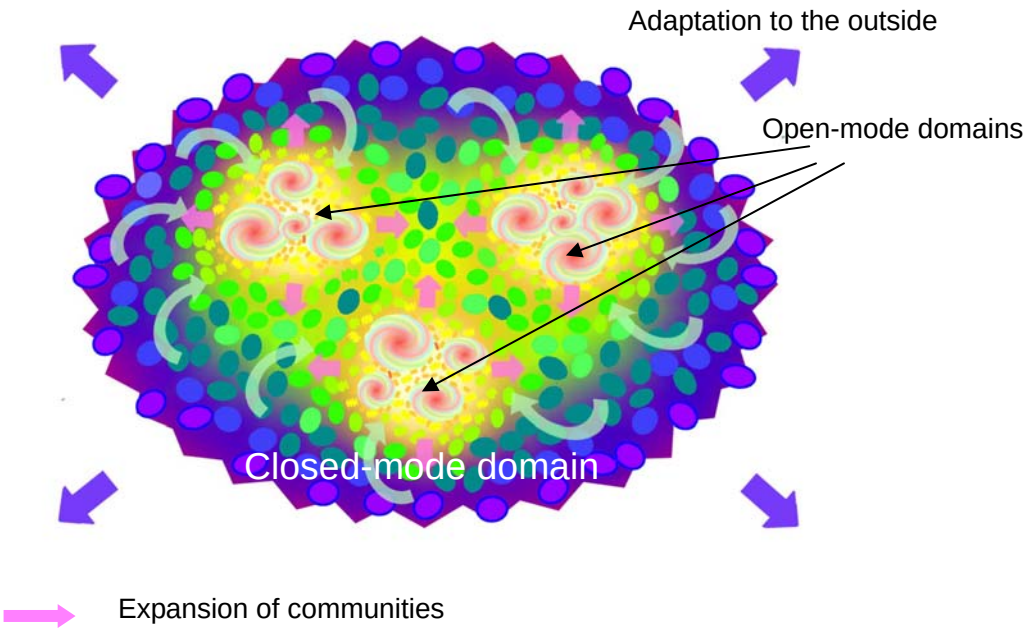
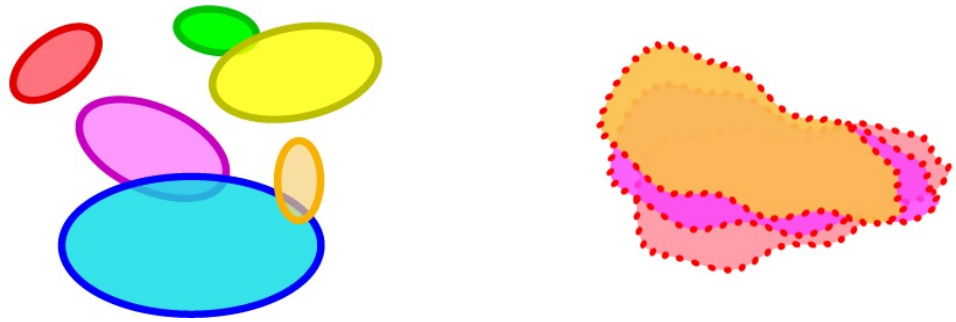


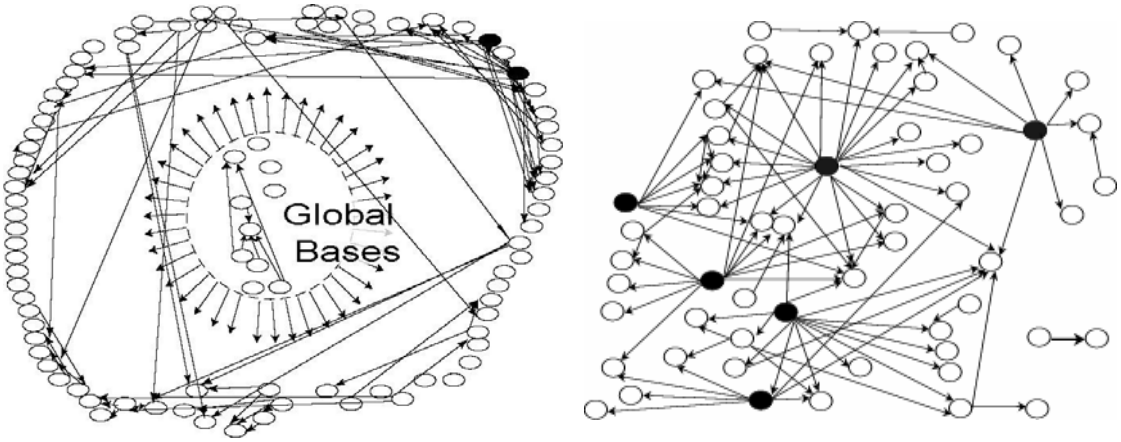
Figure 6. Adaptation to the Environment of the Society of Individuals Based on Interactions of Closed- and Open-Mode Behaviors.



(a) Closed Mode:
Discrete and Persistent Relations

(b) Open Mode:
Continuous and Variable Relations

Figure 7. Topological and Dynamical Properties of the Relations of Experienced Elements in the Dual Modes.



(a) Closed Mode: Closed and Discrete Topology (b) Open Mode: Open and Continuous Topology

Figure 8. Topological Characteristics of Behavioral Graphs Associated with the Dual Modes.

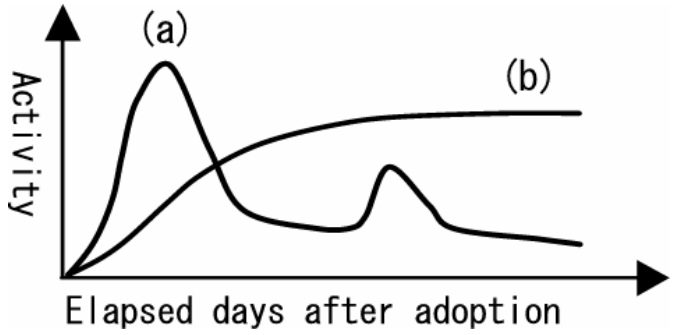


Figure 9. Typical Long-Term Activity Profiles of Dual Modes.