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デジタルシティにおけるコミュニケーション

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あらまし 本論文はデジタルシティの概念について考察し，その設計と構築のための基礎理論を提案する．デジタルシティの根本的な役割は環境におけるナビゲーション支援である．ナビゲーションでは環境に対する記号化とその意味生成が繰り返し行われるが，このプロセスはコミュニケーションを行っている者の振る舞いを通して相互作用を与え合う．本論文は，これまでの理論ではコミュニケーションの働きを十分に説明できないことを指摘し，記号論とシステム理論の概念と手法を用いた新たなコミュニケーションモデルを提案する．このモデルは，コミュニケーションを個人と社会との再帰的な相互作用における記号化一意味生成過程の一部と定義し，個人と社会を自己組織システムととらえた場合の一連の動的なプロセスを説明する．提案モデルの応用例として，様々なデジタルシティが持つインタフェースの解析を行う．

キーワード コミュニケーション，デジタルシティ，記号論

Communication in Digital Cities

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Abstract This paper investigates the concept of digital city and proposes a theoretical basis for the design and development of digital cities. The ultimate function of a digital city is to support navigation in an environment. Navigation builds on meanings of the environment resulted from semiosis (meaning-making) processes. These processes may affect each other, owing to communication. Communication is performed with signs and depends on the behavioral co-ordination of communicating parties. The classical theories do not satisfactory explain communication. The paper introduces a new model of communication that utilizes concepts and the apparatus from Semiotics and Complex System Theory and defines communication as a partial sequence of semiosis processes defined recurrently, as emerged from the interaction of at least one psychic system with one or more social system(s). The psychic and social systems are characterized as self-organizing systems; their dynamics is described. An example of the application of the proposed model to the analysis of interfaces of digital cities is given.

Key words Communication, Digital City, Semiotics

1 Introduction

Modern communication technologies allow for not only "connecting" people to each other, but accessing to various resources, whether material or information, and utilizing these resources, often regardless of their original space- and time- locations. New stable patterns of communicative and functional interactions increasingly emerge in the "virtual world," sustaining the extension of urban and economic organizations to the realm of "digitally allied" societies. One instance of these societies is the "populace" of the so-called digital cities [5].

A digital city usually comes as a distributed collaborative system comprising a range of information resources associated with a certain geographical place (e.g. a real city or region) or a specific human activity (e.g. trading or chatting). The principal function of a digital city is to support navigation of its users in the physical (geographical) or abstract (activity) space by providing relevant information in a timely manner. To do this, the digital city enables various social interactions between users and information resources. These interactions can roughly be classified into three groups: communication of the user's need or goal (e.g. sightseeing or shopping), the location of a source of relevant knowledge (e.g. a database or another user), and communication of the knowledge (e.g. as a text or diagram). A typical scenario for the interaction is that the user submits a query representing his or her goal to a search engine, which is part of the digital city, and then browses across hyperlinks generated by the system in reply to the query, interprets, finds, and retrieves information of interest. Otherwise, to locate a particular resource, the user can browse through a pre-defined hyperlink tree or network that reflects the digital city organization. In both cases, the interaction – that is the human-computer *communication* – is considered successful if the obtained information assists the user in achieving his or her goal or preferred state.

Just as a digital city is naturally composed of a number of heterogeneous recourses – system components (which can, in turn, be independently developed distributed systems), its user interface is dynamic and usually consists of multiple parts that may use different languages of different "digital genres" (e.g. text *vs.* graphics) and/or implement different and even conflicting semantics. To make the digital city "active," i.e. capable of adaptation (both at the individual and the social levels), it is necessary to develop an integrated perspective on the communication process. The latter is, however, a difficult task: any of the current holistic approaches to modeling communication, which are applied to design multipart systems, is limited in the respect that it is based on an *ex ante* analysis, which assumes the (pre)existence of a society of the system (potential) users. In the case of digital cities, however, such a society does not pre-exist as a distinct social group, but emerges in the course of using the system, after a version of the digital city has been set up and made accessible. Furthermore, the emerged society is not stable, as not stable is the structure of the system – the users as well as the resources incorporated (linked) in the digital city have internal dynamics and are mutually dependent. Being allied (functionally and/or communicatively), they create a complex system with a dynamics generally indefinable in terms of cause and effect or in terms of probabilities. Therefore, although the task of designing digital cities requires the development of an integrated and, possibly, unified perspective on the communication process, the deficiencies in the current understanding of communication have first to be eliminated or, at least, reduced to a minimum.

This paper investigates the phenomenon of communication and proposes a new model of communication appropriate for computer treatment. The model builds on the ideas of complex system theory and utilizes the apparatus of algebraic semiotics. The proposed model is applied to characterize the (cognitive and social) dynamics of communication in digital cities.

2 Navigation with a Digital City

The general task of navigation in an environment[1] can be described as a four-stage iterative process that includes [14]: 1) perception of the environment, 2) interpretation of the perception, 3) deciding whether the current goal has been reached, and 4) appropriately adjusting the behavior. Among the four stages, the last two have obviously a subjective character, whereas the other two depend on "objectively" available – sensed – information about the environment. Perception first receives and represents raw sensory data and provides for the further interpretation by combining (i.e. putting into a context) the obtained representations. When information available through the senses is not enough for establishing or re-establishing meanings (i.e. "knowledge") of the environment necessary for the decision-making, the navigator may ask for help a guide – someone, who (presumably) knows more about the environment. A digital city may be seen as such a guide: it works to enhance the navigator's sensing capabilities.

Perceptual Control Theory [10] proposes an explanation of the control mechanism for the navigation process. The theory tells us that a perceiving entity seeks to bring the perceived situation to its goal (or preferred state) by utilizing negative feedback from the environment: if the situation deviates from the goal, the entity acts and adapts, possibly changing its own state and the state of the environment, and the new situation is again sensed and estimated in respect to the goal. The loop repeats and keeps the system in a stable goal-directed (or motivated) state. A digital city can, in principle, sense its environment directly (e.g. through cameras and transducers – in the case of spatial navigation). There is, however, no other way for it

[1] For the purpose of this study, we will not distinguish the environment of a digital city as surroundings from the environment as navigation space. In both cases the environment is "that, which is not the digital city," and the latter is often part of the former.

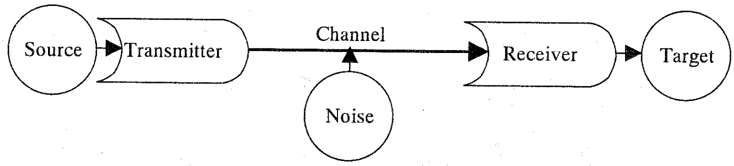

Fig. 1. The conveyor tube model

to determine the context and, hence, semantics necessary for making the sensed information meaningful, but (ultimately) by drawing on the expertise of its users and utilizing feedback from them. In this aspect, the users (together with their knowledge) are constitutive parts of the digital city that should then be considered (a realization of) a social system.

Each user's knowledge is a subjective reconstruction of the locally and selectively perceived environment. No user possesses the perfect knowledge, but being connected by means of the digital city, the users can interact with each other, thus accessing to the collective "knowledge" – once sensed or created information about the environment – that is usually far more complete and encompassing than the knowledge of a solitary user. Given the diversity and apparent subjectivism of each user's knowledge, to understand how a digital city should operate, one must clarify (at least) three principal issues: 1) what is communication, 2) what is(are) the rôle(s) of a digital city in communication, and 3) how communication reconciles the diversity of the subjective views of reality.

3 Communication Models

There are two major approaches to understanding and modeling communication processes [6]: statistical "signal-oriented" and interpretive "meaning-based." The Shannon-Weaver theory with its conveyor tube model [13] represents the former class of the approaches. The theory (and the model) assumes the following (see also Figure 1):

- There are (information) source and target involved in communication that is seen as the "exchange of information" between them through a channel. It is generally possible for an observer to judge about the correctness of information, whether sent or received.
- The source is active and initiates communication.
- The channel is passive and unstructured: "useful information" can be extracted from the transmitted signal, provided it statistically differs from (physical or semantic) noise.
- At the target side, received information is utilized by embedding it into pre-defined information structures.

Although criticized by many, the Shannon-Weaver theory currently dominates over any other theory of communication in terms of its conceptual development and significance for practice. Among the most noticeable shortcomings of the conveyor tube model, we would mention its inability to explain the phenomena of (mis)understanding, lying, and psychological effects of verbalizing thoughts and emotions. More significant (though evident) for us is, however, the fact that the Shannon-Weaver theory can contribute little, if anything, to clarifying the complexity of communication in a social context. Often, neither the target nor the source can uniquely be identified in the case of digital city (rather, there can be many sources and targets, which may or may not coincide), and it is unclear what is the rôle (apart from the straightforward "information channel" rôle) a digital city can play in communication. This makes the statistical approaches ineffective for the study of a digital city as a social system.

Striving to compensate for the limitations of the conveyor tube model, a number of interpretive models of communication have recently been developed (e.g. [1]). Rooted in the human sciences, an interpretive model postulates that:

- There are no physical target and source but interpretants – that, which follow semantically from interpretation processes.
- The observer cannot judge about the correctness and incorrectness of information: these two are subject to individual interpretation. Besides, there is no direct access to reality, and the decisive notions, like "truth" and "false," are only socially determinable.
- The target, rather than source, is active.
- Not mere information, but meaning is produced, sent, and interchanged in the course of interaction between a carrier (e.g. text or sound) and culture.

Operating with meaning, interpretive models are often defined in terms of semiotics – a science about signs, which (in the Peircian interpretation [9]) departs from the naïve treatment of signs as utter signifiers of their objects by introducing a third aspect of the representation process – the interpretant – that corresponds to the meaning connecting a sign with its object. While a more detailed introduction into semiotics will be given in the next section, declaring that a sign can have many different meanings depending on the socio-cultural context should suffice to understand Figure 2, which presents an interpretive model of communication proposed in [1].

The model sees communication as the interaction of two or more psychic systems with a shared communicative – social (cultural) – system, in course of which signifieds (products of the psychic systems) become signs (products of the social system), which have socially (culturally) determinable meaning. In this view, a digital city is to play the rôle of the social system, and the interpretive approach

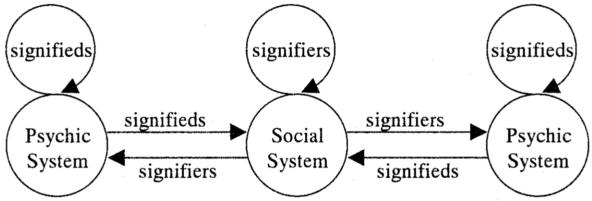

Fig. 2. The interpretive model

can (and does) explicate many of the communication phenomena overlooked in the conveyor tube framework. At the same time, however, the model appears too speculative to be useful in practice: it says little about mutual influences of the social and psychic systems (and, hence, about the dynamics of these systems), yet leaving one confused by specifying the functioning of a psychic system in terms of "signifieds" understood as either "objects" with which meaning is expressed (e.g. sound-waves) or "objects" of interpretation (i.e. that which is expressed). This, as well as the poorly matched formalization of interpretive models suggests us that to meet the modeling needs of the digital city development, a new approach, which would assimilate the advantages but remove the shortcomings of the different communication theories, needs to be devised.

4 The Approach

4.1 Terminology and Basic Assumptions

From a behavioristic viewpoint, an individual engaged in navigation develops an internal representation using those distinctions – "signs" – of the environment, which turn up solutions to the problem that are successful behaviors. Signs of such a representation arrive as "tools for indication purposes" [11]. When met in an environment, these signs (i.e. the distinctions they stand for) serve to orient the navigator, regardless of their other possible (or "actual") meanings and rôles. The navigator is not really interested in "getting to the truth," but in knowing what happens or what are possible consequences – expectations, when a sign is encountered. In this aspect, signs come up as signifiers of once successful interaction between an individual and an environment: a sign is an orientational "pointer" to not merely an object standing in a referential relation with it, but to the outcome desired for the user (e.g. "turn left after the sign-post" but not "follow the sign-post"). Signs can be considered "anticipations of successful interactions of referral" [11], emphasizing their origin and expected influence on behavior.

One can show that the behavioristic view of the grounding process of forming signs is just a specialization of the classical view that defines information as "a difference that makes a difference" to the interpreter [2]. The specialized view, however, makes it difficult to explain communication in a digital city as mere exchange, whether of information or signs, or meaning. Indeed, in the case of navigation with a digital city, not objective reality but subjective experience underlies the creation of signs. The navigator cannot frequently succeed with developing an interpretation of a sign received through communication by simply referring the sign to the observed environment – the navigator's personal experience has first to be coordinated (up to a point) with the experience of the "creator" of the sign. The latter requires something else than just sending and receiving information (signs, meaning, etc).

An advanced explanation of communication that includes aspects of information (sign) exchange as well as behavioral coordination between *autopoietic systems* can help us shed more light on the phenomenon. An autopoietic system is a dynamic system maintaining its organization on account of its own operation: each state of such a system depends on its current structure and a previous state only [7]. The structure of an autopoietic system determines the system possible (i.e. self non-destructive) behaviors that are triggered by its interactions with the environment. If the system changes its state, causing changes of the structure, without breaking autopoiesis, the system is structurally coupled with the environment. If the environment is structurally dynamical (e.g. is itself an autopoietic or self-organizing system), then both the system and the environment may mutually trigger their structural changes, sustaining the system's self-adaptation. When there are more than one autopoietic system in the environment, the adaptation processes of some of the presented systems may become coupled, acting recursively through their own states. All the possible changes of states of such systems, which do not destroy their coupling, create a consensual domain for the systems. Behaviors in a consensual domain are mutually oriented. Communication, in this view, is *the behavioral coordination resulting from the interactions that occur in a consensual domain* [3]. This definition can be used to refine and improve the interpretive model described in the previous section by introducing the dynamic aspects. To do so, let us first make clear the terminology.

In Peirce's formulation [9], semiotics studies the process of interaction of three subjects: the sign itself – the signifier, its object – that which is signified by the sign, and the interpretant – the meaning made of the sign. No sign is directly connected to an object: signs acquire meanings only when they are re-represented in (referred to) a system of interpretance that is a sign system, which creates a context (e.g. by establishing relations on signs). Naturally, the same sign may have different meanings while signifying different objects, or the same sign may have different meanings while signifying the same object, or different signs may have the same meaning while signifying the same object, and so on. Designated semiosis processes determine the meaning(s) of a sign in all the specific situations.

A semiosis process is the process of establishing the meaning of some distinctions in an environment that entails representation and re-representation of these distinctions as a sign over levels of interpretation (that form different systems of interpretance), where every level is governed by and adopts certain developmental rules and axioms called norms. The norms reflect different aspects of human behavior and can be classified into five major groups: perceptual (to respond to peculiarities of sensing), cognitive (to deal with cultural knowledge and beliefs), evaluative (to explain personal preferences, values, and goals), behavioral (to delineate behavioral patterns), and denotative (to specify the choice of signs for signifying). Semiosis comes as a natural organizational process: it organizes signs in a partial level-hierarchy by ordering them so that signs of objects (which can also be signs) of level N-1 for processes and structures of level N+1 are placed on level N. The lowest-level signs, e.g. (manifestations of) physical objects, behaviors, emotions, and the like, are perceived or realized through their distinctions and may get a representation at an "intermediary" level of norms, reflecting interpretive laws of a higher, experiential and environmentally (physiologically, socially, technically, economically, etc.) induced level, which determines "meanings" for the lower-level signs. This simplified three-level structure corresponds to a single semiosis process, whereas navigation in an environment engenders multiple semiosis processes and results in the creation of a multi-level sign system with a potentially infinite hierarchy of dynamic interpretive levels.

A user of a digital city typically deals with a fragment of the global, i.e. loosely shared through the environment (that may be seen as the lowest semiotic level) by all the users, system of signs. The fragment is, however, distinctively ordered in an interpretive hierarchy peculiar to the user's experience and the norms he or she adopts. Hierarchies created by different users may be different in terms of the order as well as the coverage, and they may run on different time-scales. Having been (communicatively) combined into one structure, the fragments may form a global but partial and often implicit "hierarchy." This global hierarchy constitutes the functionally invariant structure of a digital city. It allows for producing "meanings" for the system internal (adaptation) needs out of (represented) perceptions based on experience (received through, for instance, feedback) currently prevailing in the society of digital city users. The hierarchy should have essentially an ordering, i.e. affecting the interpretive levels rather than signs within a level, dynamics [8].

Unlike the case of individual navigation, where perceived and conceived signs may need not be articulated explicitly, the development and operation of a digital city neatly builds on communicative use of a multi-level sign system representing the environment and the digital city itself. This sign system can be externalized – derived from the digital city structure – as a language defined in a very general (behavioristic) way. The digital city "describes" (and interacts with) its environment with this language, which has a syntax reflecting the organization of the environment, semantics defining meanings of the environment, and pragmatics characterizing the effect of the language use. The language is to reconcile the subjectivism and diversity of individual perceptions through communication.

4.2 System-Theoretic Semiotic Model of Communication

We will consider communication as a (usually finite) partial time-sequence of interdependent (through signs understood as behaviors, and in the sense of the observed behavioral coordination) semiosis processes $C=\{S_1,S_2,S_3,\ldots,S_k\}$, where $S_t=\{Object_t,Sign_t,Interpretant_t\}$ and t is a discrete time-mark corresponding to a single semiosis process.

We will assume that all the psychic (or any other) systems involved into communication are (higher order) autopoietic systems acting in a consensual domain. Each of these systems belongs to at least one (self-organizing) social system that is a projection of the consensual domain. We will also assume that the psychic (system) state is composed of interpretants (meanings) and is equivalent (or corresponds) to the totality of subjectively (i.e. experientially) effective interactions (behaviors), while the social (system) state is composed of signs and is equivalent to the totality of socially valid (i.e. maintaining the social system) interactions. The dynamics of a self-organizing system is generally described as follows:

$$\begin{cases} \mathbf{x}(t+1) = \mathrm{f}(\mathbf{x}(t), y(t)), \\ y(t+1) = \mathrm{g}(y(t), \mathbf{x}(t+1)), \end{cases} \tag{1}$$

where $y(t)$ is the state of the system at time t, $\mathbf{x}(t)$ is the vector of states of the system parts, which constitute its structure, and f and g are some operators specifying the behavior of the system parts and the system as a whole, respectively. The dynamics of the communication process is then described by the following equations:

$$\begin{cases} \mathbf{Objects}_{t+1} = \mathrm{Externalizing}(\mathbf{Objects}_t, PsychicState_t), \\ PsychicState_{t+1} = \mathrm{Interpreting}(PsychicState_t, \mathbf{Signs}_{t+1}), \end{cases} \tag{2.1}$$

and

$$\begin{cases} \mathbf{Signs}_{t+1} = \mathrm{Filtering}(\mathbf{Signs}_t, SocialState_t), \\ SocialState_{t+1} = \mathrm{Adjusting}(SocialState_t, \mathbf{Objects}_{t+1}), \end{cases} \tag{2.2}$$

where "**Objects**" is a state vector representing the behaviors, which are (expected to be) individually effective, and "**Signs**" is a state vector representing the behaviors socially valid. "Externalizing" and "Interpreting" are operators that represent the uttering and understanding processes, respectively; likewise, "Filtering" and "Adjusting" represent the corresponding (implied) processes of social dynamics. (In the formulas, neither "social" nor "personal" time is represented explicitly, but by the effect they have on the semiosis processes.)

The simultaneous equations of (2.1) and (2.2) allow us to "qualitatively" characterize communication as a complex semiosis process (see Figure 3). (It is understood that the number of equations of the form (2.1) and (2.2) necessary to define a particular communication depends on the number of the psychic and social systems involved.) To refine and make these formulas "quantitative," i.e. appropriate for computer treatment, the apparatus of algebraic semiotics can be used [4]. For the purposes of this paper, we will consider a sign system Ξ as a logical theory that consists of sets of signs, which have sorts, together with some operators used to build up new signs from signs already existed, some partial orderings on sorts and operators, and relations and axioms that constrain the possible signs. We will call a semiotic morphism $\mu:\Xi\rightarrow\Xi'$ a mapping (translation) from a sign system Ξ to a sign system Ξ'. This mapping is composed of partial functions defined on the sign system elements, and it preserves some of the structure of the first system.

Let us introduce the notion of basic semiotic component as follows:

$$\mu_{t+1} : f_t[\Xi_t] \xrightarrow[p_{t+1}]{} \Xi_{t+1}, \qquad (3)$$

where f_t is a (composition of) semiotic morphism(s) that specifies the dynamics of signs in Ξ_t under the condition of communicative closure – i.e. when no elements are adopted into the system through communication, μ_{t+1} is a semiotic morphism that represents a translation from Ξ_t to Ξ_{t+1}, and p_{t+1} is the probability of μ_{t+1}. The communication process can be represented as a non-empty set of pairs of recursively defined sequences of basic semiotic components with the following parameters (A is for one and Ω is for another sequence in a pair):

$$A = \{M^A, P^A, F^A, \Xi_{objects}\}, \qquad (4.1)$$

and

$$\Omega = \{M^\Omega, P^\Omega, F^\Omega, \Xi_{signs}\}, \qquad (4.2)$$

where A is the model of a psychic system that includes M^A a set of semiotic morphisms μ_{t+1}, P^A a set of probabilities for each μ_{t+1} in M^A, F^A a set of semiotic morphisms f_t, , and $\Xi_{objects}$ a sign system representing subjectively effective behaviors (i.e. interactions) at t=0; t=0,...,k, k is the number of (observed) behaviors – objects – of the psychic system; Ω is the model of the social system with analogously defined M^Ω, P^Ω, and F^Ω, and Ξ_{signs} representing socially valid interactions.

It can be seen that A and Ω correspond to the representations of (2.1) and (2.2), respectively. μ-type morphisms are to define the internal dynamics – state

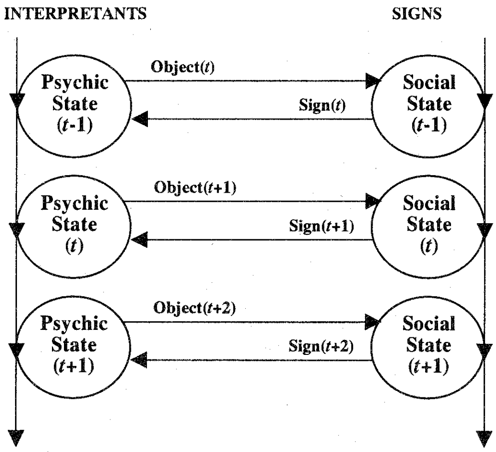

Figure 3. Semiosis of communication (also see Figure 2)

transition – of the psychic (social) system caused by interpretation (adjustment), and p is to reflect the indirect character of the state representation (e.g. potentially multiple meaning of the same object or potentially multiple objects of the same sign). f-type morphisms are to specify the process of "externalizing" the system inner state. $\Xi_{objects}$ is, in effect, the psychic system's language, and Ξ_{signs} is the language of the social system.

The system-theoretic semiotic model defined with (4.1)-(4.2) describes communication as the interaction between two self-organizing systems, where one system – psychic – may be perturbed by signs and produces objects (behaviors), and another system – social – may be perturbed by objects and produces signs. The social system works to filter communications out of behaviors and, on the other hand, to buffer behaviors against the uniformity of socio-cultural norms. The cognitive and social dynamics of the communication process are specified with the semiotic morphisms of A and Ω, respectively.

The goal (motivation) of a communication for a psychic system can be understood in terms of the model as to reach a certain inner state through perturbations by signs. Communication is successful (or effective) if $\Xi_{objects}\subseteq\Xi_{signs}$; besides, communication is successful to a degree if $\Xi_{objects}\cap\Xi_{signs}\neq\varnothing$ that establishes the *sufficient condition* of communication. By the definition of communication, the *necessary condition* is the coupling of the psychic (through M^A) and social (through F^Ω) systems.

5 Analyzing Digital Cities

The task of digital city design can be formulated as to ensure successful communication of the system's users. To do so, an obvious solution would be to build and appropriately apply (e.g. by every time generating Ξ_{signs} fitting to each user's background) models of the social and psychic systems involved into communication. It is important to note, however, that the actual (inner) states of psychic and social systems are not visible (nor accessible) from the outside and in each case, it is only the outcome – $\Xi_{objects}$ and Ξ_{signs}, not the states available for external evaluation. Perhaps, the only possible solution is thus to build up (estimations of) $\Xi_{objects}$ and Ξ_{signs}, calculate their intersection, and make the interface conducting communication in terms of this intersection. Naturally, the greater the intersection of the languages, the better the communication. Provided that the psychic and social systems are dynamic, the languages $\Xi_{objects}$ and Ξ_{signs} cannot be fixed, and the system should be able to dynamically develop $\Xi_{objects}$ and Ξ_{signs} and calculate their intersection in every single case of the user's query. This can be done by implementing the formulas (4.1) and (4.2) with an active interface (also see Figures 3 and 2). In Table 1, we present several digital cities and attempt to analyze to what extent and how their (user) interfaces realize (or correspond to the principles represented by) these formulas.

The analysis shows us that user interfaces of the digital cities (but TalkMine [12]) offer rather a limited support of communication. In most cases, it is assumed by default that to communicate, the user must know some of the language (and of its syntax and semantics) of the system (i.e. of the social group that the system stands for). The user is then required to appropriately adjust his or her language to express the psychic system state (e.g. the understanding of his or her goal), and each element of the language (e.g. a keyword) is to have its specific meaning. The social language is pre-defined by the designer, who may also modify this language, based on the users' feedback and/or results of an opinion poll. Few interfaces provide for active (i.e. based on the models of psychic/social systems) communication support, and only one – TalkMine – dynamically builds estimations of the personal and social languages. Overall, the interfaces do enable communication (as the underlying assumptions about the languages are usually general enough), but the effectiveness of the communication process is arbitrary and unpredictable in every particular case. (It should be noted that the analysis presented in Table 1 reflects the authors' experience of dealing with the digital cities; the description of TalkMine is based on [12].)

6 Conclusions

Among the results of the presented study, we would first like to point at the clarification of communication as a socio-cognitive phenomenon and at the explication of a digital city user interface as an active communication device, which is, on the other hand, a realization of a social system in the form of a language. Some implications of these results for the design of digital cities are as follows. A digital city (as well as any other multi-media dynamic information system) should co-ordinate communication at both the personal (by adjusting its interface to the social system) and the social (by adjusting the interface to the user) levels. This will improve the effectiveness of communication and reduce the connected costs by reducing the number of necessary human-computer interactions. The semantics of the communication language (and, therefore, the structure of the human-computer interactions) is determined by the users of the digital city (both individually and socially) rather than by some "objective" laws or by the structure/contents of the system. The interface should be able to dynamically adjust the semantics as it evolves, instead of building on a pre-defined and fixed "universal semantics" (e.g. an ontology).

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Table 1

Source (HTTP or reference)	Description	MODELS					
		Psychic System, A			Social System, Ω		
		Language, $\Xi_{objects}$	Dynamics		Language, Ξ_{signs}	Dynamics	
			M^A (P^A)	F^A		M^Ω (P^Ω)	F^Ω
home. digitalcity. com	Locally-focused (the US) online information	Not support	–	–	Keywords and hyperlink directory	Manually, based on feedback (e-mail or online) from users	Not support
www. digitalbristol. org/index.html	Online information about Bristol, UK	Options (news, search function, opinion poll, etc.)	Manually	Not support	Keywords and hyperlink directory (for search), questionnaire (for ranking)	Manually, based on feedback from users (questionnaire)	Not support
machigoo. ne.jp	Locally-focused (Japan) online information	Registration (personal data, geographical location, etc.)	Manually	Not support	Keywords, hyperlink directory, and phone number (for search), rating (for recommendation)	Recommendations based on users' rating (p=1)	Sorting recom-mendations based on the location
www. mapion. co.jp	Locally-focused (Japan) online information	Marks on a map	Manually	Not support	Keywords, hyperlink directory, and map (for search)	Manually, based on feedback from users (questionnaire)	Not support
www. timescity. com	The online city guide of India	Not support	–	–	Keywords and hyperlink directory	Manually, based on feedback (e-mail or online) from users	Not support
my.yahoo. com	Customi-zable Web-portal	Registration (to customize the structure and contents of the index page)	Manually	Not support	Keywords and hyperlink directory (for search), rating based on user sampling audit	Recommendations based on social data (nation-wide polls?) (p=1)	Sorting recom-mendations based on the registration
citeseer. nj.nec. com/cs	Science digital library	Not support	–	–	Keywords, hyperlink directory, and rating (for search)	Directory ranking depends on users' rating (p=1)	Not support
www. amazon.com	E-bookstore	Categories and cookies	Based on the user's buying history (p=1)	No data	Keywords and hyperlink directory (for search), order (buying) and review (users can write reviews about items)	Directory ranking and recom-mendations depend on users' rating and buying practice (p=1)	No data
windowsupdate. microsoft. com	Update service for the MS Windows OS family	System configuration	Based on the current configu-ration (p=1)	Yes, prompt for confir-mation	"Yes/No" check-box	Not support	Not support
www. recruitnavi. com	Online job-finder	Registration (job preferences)	Manually	No data	Questions and answers/opinions (FAQ)	The contents of FAQ depends on the users' interactions (p=1)	Not support
TalkMine [12]	LANL Digital Library	Individual profile	Based on the user's semantics (**P^A** through evidence set membership)	Yes	Keywords, natural language (titles)	Identification of social groups based on the statistical analysis of users' practice (**P^Ω** is determined by the parameters of the analysis)	Based on the practice prevailing within each social group