A SYSTEM APPROACH TO INFORMATION STRUCTURING IN THE CONTEXT OF SOCIAL INTERACTION

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Abstract: *Social interaction always includes communication, or information exchange. In this exchange information has different properties that impact the communication process. These properties allow us to separate several types of information and formulate conditions determining what type of information is more efficient in a certain style of communication and what type of information to specific communication parties.*

Keywords: *information, communication, representation, carrier, society,*

Introduction

Social interaction always includes communication, or information exchange. In this exchange information has different properties that impact the communication process. These properties allow us to separate several types of information and formulate conditions determining what type of information is more efficient in a certain style of communication and what type of information to specific communication parties.

There different approaches to the development of information theory. Some researchers base their concept of information on some particular properties, types of information or categories of information models. Examples are Shannon's statistical information theory [Shannon, 1948], semantic information theory of Bar-Hillel and Carnap [Bar-Hillel and Carnap, 1958], information theory of Mazur [Mazur, 1970] or algorithmic information theory pioneered by Solomonoff [Solomonoff, 1964], Kolmogorov [Kolmogorov, 1965] and Chaitin [Chaitin, 1977]. Other researchers try to compose a comprehensive concept of information. Examples are the general theory of information created by Burgin [Burgin, 1995; 2010] or the general information theory pioneered by Markov [Markov, et al, 1993; 2003; 2006]. The research presented in this paper is developed in the context of the general theory of information, taking into account other approaches.

The goal of the research is achieving better understanding of social interactions and information processes on the social level. Mathematical models of these processes are aimed at prediction of consequences of information creation and utilization, at optimization of information processes and at construction of more efficient social systems.

2. System Roles in Information Interaction

Social interaction involves not only individuals but also systems of higher order – social groups, organizations and institutions. For instance, corporations are legal "persons," and, like individuals, enter into binding legal contracts. Even single agents need not just interact on their own - typically, they also form groups and other collective agents, whose behavior may not be totally reducible to that of individual members. To unify these situations, we speak about social systems, which can individuals, social groups, organizations, institutions and so on.

A system can acquire different roles in its interactions. In this study, three roles are considered: an object, subject or agent.

Definition 1. A system is an *object* if it is treated (may be, temporarily or in abstraction) as a passive entity with which another system is dealing, e.g., is observing, acting on or referring to.

For instance, observes and/or collects information about another system *Q*. In this process, *Q* is an object and *R* is a subject. An object can only receive information, while other systems can extract information from an object, transmit information to an object or store information in an object.

Definition 2. A system is a *subject* if it actively deals with another system, e.g., observes, acts on or refers to.

When information is transmitted from a system *A* to a system *B*, then the first system is in the role of a subject, while the second system is in the role of an object. When transmission goes in the opposite direction, the roles of the systems are changed.

In other words, in the standard communication structure

	channel	
Sender	⟶	**Receiver/Receptor**

The Sender plays the role of a subject, while the Receiver/Receptor and channel play the role of a object.

Definition 3. A system is an agent if it actively interacts with other systems, perceiving its environment and acting upon this environment.Thus, an agent has special means (subsystems) called sensors for perceiving its environment and special means (subsystems) called *effectors* for acting on this environment [Burgin and Dodig-Crnkovic, 2009].

Note that an object and a subject are, in some sense, dual concepts because to be a subject, it is necessary to have an object, and to be an object, it is necessary to have a subject. At the same time, an agent is an independent concept, which is self-dual.

3. Information Typology in the Context of Social Interaction\

Information roles of systems in social and other interactions allow us to separate different type of information.

Definition 4. *Information in* a system is information that can be reached, received or extracted/obtained from this system by another system.

This gives us three kinds of information in a system: *reachable*, *receivable* and *extractable* information.

The following example shows the difference between these three types of information. Imagine you have a book in a language that you do not know. Then information in this book is reachable – you can observe the text but it is not extractable until you learn this language and it is not receivable until somebody translates this book and you get this translation.

The concept of information in a system *R* is relative to a system that reaches, receives or extracts/obtains this information from *R*. That is why we usually speak about information in a system *R* with respect to a system *P*. Naturally information in a system *R* can be different with respect to different systems.

Lemma 1. Receivable information is reachable, while extractable information is also reachable.

There are situations when it useful to know how information in a subsystem is related to information in the whole system. This relation is not unequivocally straightforward as the following result demonstrates.

Proposition 1. Information in a subsystem *Q* of a system *R* is information in *R* with respect to a system *P* only if the subsystem *Q* is accessible by *P*.

For instance, information in all books from a library is a part of information in this library.

However, it is also possible to consider *comprehensive information in* a system *R*, which consists of all information in *R* for which there is a system *P* that can reach, receive or extract/obtain this information from *R*.

Proposition 1 implies the following results.

Corollary 1. Comprehensive information in a system *R* includes comprehensive information of its subsystem *Q* only if any system that can reach (receive or extract/obtain) information from *Q* can do this interacting with *R*.

Corollary 2. Information in a system *Q* with respect to a system *P* is included in the comprehensive information of a subsystem *R* only if for any information that system *P* can reach in (receive or extract/obtain from), there is a system *T* that can do the same through the system *R*.

Information in a system is closely related to information of a system.

Definition 5. *Information of* a system is information that this system can (perhaps, potentially) use, for example, can send to another system.

It is possible that information in a system does not coincide with information of this system. For instance, in an individual, there is information about all her organs, but as a rule, she cannot use, at least, some of this information. Thus, such information will be information in but not information of this individual.

At the same time, information of an individual can be outside this individual, for example, stored on the Internet or in a computer.

There are three kinds on information of a system *R*:

- *Active* information is information the system *R* is using.
- *Passive* information is information the system *R* can use.
- A*ctivated* information is information the system *R* used.

In the context of social interaction, we are dealing with conscious agents. To model such agents, we define *consciousness* as an information processing subsystem of this agent that contains a model of this agent and his/her/its environment, basing actions of the agent on this model. Consequently, information of an agent stored in her/his consciousness is called *conscious information*. Note that conscious information can be not only active but also passive.

Similar to knowledge, information of a system can be *explicit* and *implicit* [Polanyi, 1962].

Implicit information of a system is information that this system can (perhaps, potentially) use on the subconscious level.

There are also two kinds of explicit information of a system. This makes the concept of conscious information more precise.

Verbatim explicit (or *verbatim conscious*) information of a system *R* is information of *R* such that *R* is aware of it.

The highest level of verbatim conscious/explicit information of a system *R* is *transmittable information* of *R*, i.e., conscious/explicit information of *R* that *R* can transmit (send) to another system, e.g., to articulate.

Definition 6. *Information to* a system *R* is information that is sent or intended for sending to the system *R*.

In this case, to the system *R* is called the *target system*.

In many examples, only information to individuals as target systems is discussed. However, information to social groups, organizations and even institutions as target systems is also very important.

It is possible to define different operations with *information to*. One of the main operations is the free amalgamation of information. To define it, let us assume that there is a set of portions of information I_1 , I_2 , I_3 , … , I_k directed to systems R_1 , R_2 , R_3 , … , R_k .

Definition 7. The *free amalgamation* of the portions of information I_1 , I_2 , I_3 , … , I_k is the portion of information I that is directed to the system R that consists (as a set) of systems R_1 , R_2 , R_3 , … , R_k .

It is denoted by $I = \coprod_{i=1}^{k} I_k$.

For instance, imagine that you sent letters to your friends Alice and Bob. Then the free amalgamation of information in the letter to Alice and in the letter to Bob is all information in both letters.

Note that free amalgamation of information to can change the level of the target system. For instance, if all are individuals R_1 , R_2 , R_3 , … , R_k , then R is a group.

Proposition 2. The free amalgamation of information to is an idempotent, associative and commutative operation.

As a type, *information to* is also conserved in sequential compositions [Burgin, 2011; 2011a]. Definitions directly imply the following result.

Proposition 3. If I is information from a system Q to a system R and J is an information from a system R to a system T, then their sequential composition in the sense of [Burgin, 2011; 2011a] is information from Q to T.

This result shows that *information to* represents information transmission on the level of uninterpreted data.

Definition 8. *Information for* a system R is information that is adapted for or adjusted to the system R.

In this case, to the system R is also called the *target system*.

Very often people direct information to different systems without making it information for these systems. The result of such behavior is misunderstanding, impaired communication and sometimes broken relations.

Difference between information for and information to is important for effective communication. Indeed, in communication, people exchange information. However, when a person transmits only information to another person and it is not information for that person. Then the recipient gets a message but can miss all or part of information in this message.

The latter situation is especially critical for education – if a teacher does not adapt his messages to the level of his students, then the students get very little (if any) knowledge from such teaching. In our times, when a teacher has to communicate with a substantial group of students – sometimes with more than hundred people, very often it is necessary to repeat the same material several times adapting it to different groups in the class because, as a rule, there are students on different levels of knowledge and abilities in the same class.

It is also possible to see the difference between information for and information to if we consider the definition of information given by Markov, et al. They write [Markov, et al, 2003]:

"We may say that the *reflection* of the first entity in the second one is "*information"* for the first entity if there is corresponded reflection evidence".

We can see that information in this sense is *information for* the first entity. At the same time, not all *information to* the first entity satisfies all conditions of this definition because it may lack the necessary evidence.

To prepare *information for* a special consumer/user, a new type of software systems called *recommender systems* or *recommendation systems* emerged [Ricci, et al, 2010]. They seek to predict interests of a given user by rating the preference that the user would give to an item, which can be a product, such as books, music, hotels or movies, or social element, e.g., individuals, groups or organizations. Recommender systems use an *object model* built from the characteristics of an item (content-based approaches) or the user's social environment (collaborative filtering approaches). This model is compared to the *subject model* of user preferences.

Recommender systems typically produce a list of recommendations for the user in one of three ways: either through collaborative or by content-based filtering or by a combination of both [Ricci, et al, 2010]. In *collaborative filtering* a subject model from a user's past behavior (items previously purchased or selected and/or numerical ratings given to those items), as well as similar decisions made by other users, is constructed and then used for prediction or rating items that the user may have an interest in. *Content-based filtering* utilizes a series of individual characteristics of an item in order to buils an object typological model and to recommend additional items with similar properties.

An important property of *information for* is its type conservation in sequential compositions.

Proposition 4. If *I* is information from a system *Q* to a system *R* and *J* is an information from a system *R* for a system *T*, then their sequential composition in the sense of [Burgin, 2011; 2011a] is information from *Q* for *T*.

Corollary 3. If *I* is information from a system *Q* for a system *R* and *J* is an information from a system *R* for a system *T*, then their sequential composition is information from *Q* for *T*.

Note that in contrast to sequential composition, the free amalgamation of *information to* does not always preserve *information for*. Taking the given above example of information in letters, we can see that while the letter to Alice can contain information for Alice and the letter to Bob can contain information for Bob, it is possible that information in both letters is not information for Alice and Bob as one system. For instance, information in both letters can be contradictory or confusing, when it is combined together.

Similar situation was empirically discovered by TV producers. For a long time, TV programs were produced for all people, i.e., without a definite target system. That is why information in these programs was *information to* but not *information for* the majority of the tentative viewers. When it was observed that such programs did not attract sufficiently big audience, TV orientation changed and programs became oriented at a definite audience, e.g., programs for children or programs for women. These programs have become much more efficient because they had had *information for* a definite target system. Note that in this example, information includes not only cognitive information, which gives knowledge, but also emotional/affective and effective information, which brings emotions and attracts people [Burgin, 2010].

This example shows that not only *information for* individuals as target systems is important but also *information for* social groups, organizations and even institutions as target systems can be very valuable. Now a diversity of psychological and technological tools has been developed for information adaptation.

It is possible to distinguish three modes of information adaptation:

- Selection of relevant information.
- Selection of relevant information representation.
- Selection of a relevant information carrier.

All these three modes are especially important in social communication. For instance, when a person sends information to another person, who cannot understand this information, then the second person will not accept this information. Even more, such situation with irrelevant information can cause a negative reaction from the second person. Imagine a mathematician who starts explaining a theorem from advanced field of contemporary mathematics to a truck driver.

Selection of relevant information representation is also very important in social communication. Imagine what will happen if send a letter to your friend in a language that your friend does not know.

Choosing a relevant information carrier plays a key role in social communication. For instance, if want the recipient of your information to get this information at the same day, you must not send it by a regular mail. Better choose e-mail or make a phone call. However, if the recipient does not read his e-mails, then it would be unreasonable to send your information in the form of an e-mail.

The process of acquiring a material representation and/or material carrier is called materialization of information. An example of such materialization is the situation when a scientist has an idea and then he writes this idea down on the paper or creates a file with a description of this idea. In this case, it is possible to treat idea as information. Then the text on the paper is a material representation of this idea, while the paper with this text is a material carrier of the idea. When this idea is materialized in a file, then text in the file is a material representation of this idea, while the file is a material carrier of the idea.

In a similar way, artists and sculptors materialize their vision in paintings and sculptures. Any person sending information finds a material representation or material carrier for this information, in such a way, performing information materialization. A general schema of materialization is studied in [Burgin and Markov, 1991].

Let us consider one more type of information.

Definition 9. *Information about* a system is information that allows one to get knowledge about this system.*Information about* allows one to discern *information to* and *information for*. For instance, a user searches for information about birds on the Internet and the search engine she uses gives her information about words. This will be *information to* her but not *information for* her.

It is possible to discern different kinds of *information about*. Here are two of them.

Holistic information about a system R is information about the system R as a whole.

Comprehensive information about a system R is information that includes any information related to the system R.

For instance, information about a subsystem of a system R is not always included in the holistic information about R but is always included in the comprehensive information about R.

Definition 10. *Information from* a system is information that comes from this system.

Note that it is possible that a message from one system can contain information from another system. For instance, in a letter from an individual A to an individual B, it is written: “Your aunt sends her regards to you.” Thus, such the message in a form of a letter from the individual A contains information from another person to B.

It is possible to define different operations with *information from*. In many cases, operations with *information to* as with other types of information induce corresponding operations with *information from*. For instance, in such a way, the free amalgamation of *information from* is defined. Namely, let us assume that there is a set of portions of information I_1 , I_2 , I_3 , … , I_k . Then Definition 7 determines the *free amalgamation* of the portions of information I_1 , I_2 , I_3 , … , I_k transmitted from a system Q to systems R_1 , R_2 , R_3 , … , R_k .

Proposition 2 implies the following result.

Proposition 5. The free amalgamation of information from is an idempotent, associative and commutative operation.

An important problem is measurement of different types of information. Shannon’s entropy is a measure of *information from* a sender. At the same time, there are different measures of *information for*. For instance, an important measure is information *utility*.

Cockshott and Michaelson use *information utility* as a measure of the uses to which information can be put [Cockshott and Michaelson, 2005]. It is possible to formalize information value in the sense of Cockshott and Michaelson using dual measures to time complexity for classes of algorithms. Such dual measures and more general dual measures to computational complexity are introduced and studied in [Burgin, 1982].

Gackowski introduces several economical attributes of information, which reflect its economical value [Gackowski, 2004]. In business environment, money are the main criterion. As a result, several measures of information quality were constructed by Gackowski.

Utility value V(I) *of information/data I* is determined by the following formula:

$$V(I) = V_R(D + I) - V_R(D)$$

Here $V_R(D + I)$ and $V_R(D)$ are the cost (e.g., monetary values) of actions or business operations with and correspondingly, without the additional information I.

Net business utility value $V_N(I)$ *of information/data I* is determined by the following formula:

$$V_N(I) = V(I) - C(I)$$

Here $C(I)$ is the procurement (acquisition) cost (e.g., monetary value) of the additional information I.

However, people are mostly interested not in the *a posteriori* value but in what is possible to gain in future. That is why expected values of the considered characteristics are more adequate for economic applications.

Here the *expected utility value* E$V(I)$ *of information/data I* is determined by the formula:

$$\mathrm{E}V(I) = V(I) \cdot [1 - \text{risk factor or failure rate}]$$

The approach of Harkevitch is based on utility of information for [Harkevitch, 1960]. Positing that from the pragmatic perspective, the value of information is its usefulness in achieving some goal, he defines the pragmatic measure of information as the gain in the probability distributions of the receiver's actions, both before and after receipt of a message in a pre-defined ensemble. Different goals can assign different values to the same portion of information. Thus, value of information is defined for a mission oriented system R. If I is some portion of information, then the *value* of this information is equal to the caused by I change of the probability $p(R, g)$ of achievement of a particular goal g by the system R. Thus, if $p_0(R, g)$ is the probability of achievement of g by R before R receives information I and $p_1(R, g)$ is the probability of achievement of g by R after R receives information I, then the value $J(I)$ of I for R with respect to the goal g is equal to

$$J(I) = \log_2 (p_1(R, g) / p_0(R, g)) = \log_2 p_1(R, g) - \log_2 p_0(R, g)$$

Bongard's approach is based on an extension of the Shannon's measure of information [Bongard, 1963; 1967]. As in other pragmatic approaches to information measurement, he considers a system R that uses information for solving problems by a sequence of experiments with an object. In this process, the system R can get information from other sources. Received information can change the number of necessary experiments and thus, to alter complexity of the problem that is solved. This change is used to find the *value of information for*.

To formalize this idea, it is assumed that a problem a_i has the unique answer b_i with the probability p_i. At the same time, the system R that makes experiments tries the answer b_i with the probability q_i. Then the average number of experiments is equal to $1/q_i$ and uncertainty of the problem is defined as

$$\log_2 (1/q_i) = - \log_2 q_i$$

Thus, probability of this situation is equal to p_i and uncertainty for a collection of problems $A = \{ a_i ; i = 1, 2, 3, \dots , n\}$ is equal to

$$H(A) = -\Sigma_{I=1}^{n} p_i \log_2 q_i$$

This allows Bongard to define information received by the system R, or more exactly, the value of this information equal to

$$I = \Sigma_{I=1}^{n} p_{1i} \log_2 q_{1i} - \Sigma_{I=1}^{n} p_{0i} \log_2 q_{0i}$$

Here p_{1i} and q_{1i} are probabilities after R receives information I and p_{0i} and q_{0i} are probabilities before R receives information I ($i = 1, 2, 3, \dots , n$).

Another approach to the value of information also stems from utility theory where a decision-maker aims for maximization of expected utility based on known information. The formalization uses a *probability space* $(\Omega, \mathbf{F}, \mu)$ where Ω is interpreted as the set of states of the world, subsets of Ω from **F** are called *events*, **F** is a σ-algebra of events, i. e., **F** has Ω as a member, is closed under complementation (with respect to Ω) and union, and μ is the decision-maker's probability measure. Information is modeled by partitions of the set Ω of states of the world

[Marschak, 1964; Aumann, 1974; Hirshliefer and Rilley, 1979]. Each partition is a finite set of pairwise disjoint elements from **F** the union of which is equal to Ω.

Partitions are estimated by a function f: $\mathbf{P} \rightarrow \boldsymbol{R}$ from then set **P** of all partitions of the set Ω into the set of real numbers $\boldsymbol{R}$. This function indicates the value of a partition for the decision-maker. As partitions model information, or give the information structure, f is called an *information function* when it satisfies the maximality condition related to strategies of the decision-maker and his expected utility. Information functions represent the value of information. Different properties of information functions have been studied.

When the decision-maker has information that the situation she is dealing with is represented by a partition P and then receives information that the situation is actually represented by a partition Q, which is a refinement of P, then it possible to treat the difference $f(Q) - f(P)$ as the value of additional information to the decision-maker. Observe that the value of a given portion of information may be negative in some cases.

Value of information has different interpretations. For instance, utility is often identified with money obtained by the decision-maker. In this case, the value of additional information to the decision-maker is the maximal price she/he will be willing to pay for this additional information. Note that information value is not necessarily cost although contemporary society tends to estimate all other values in money.

The most popular approach to measuring *information for* is based on the assumption that the value of information has to reflect an outcome of choice in uncertain situations [Hirshliefer and Rilley, 1979]. The outcome is estimated as the expected value of the income that resulted from making a decision. This estimate depends on the following factors or determinants [Hilton, 1981]:

- (*Action flexibility*) The structure of the decision-maker's actions.
- (*Initial uncertainty*) The extent of uncertainty of the decision-maker.
- (*Payoff function*) What is at stake as an outcome of the decision, i.e., what are tentative losses when a wrong decision is made.
- (*Quality of information*) Such attributes of information as timeliness, accuracy, and clearness.
- (*Price of information*) The price of information under consideration.
- (*Price of substitutes*) The price of the next-best substitute of this information.

In this context, for example, a portion of information has no value, or more exactly, the value is nil, when there are no costs associated with making the wrong decision or there are no actions that can be taken in light of this information.

One more socially constructed measure of *information for* is information importance.

4. Structures of Information Dynamics

Combining different types of information considered in the previous section, we obtain structures of information dynamics. Let us contemplate some of them.

Definition 11. Information from a system Q to a system R is called an *information direction* or *directed information* when this information is transmitted.

On the one hand, information directions are some kinds of vectors in system spaces when these system spaces are vector spaces [Burgin, 2010]. In particular, it is possible to add and subtract information directions when they satisfy some natural conditions. For instance, it is possible to consider the space of information directions from a fixed system Q_0 to systems from a given set **V**. In this case, it is possible to add information from Q_0 using the free amalgamation described in Definition 7.

On the other hand, information directions are some kinds of arrows in system spaces when these system spaces are categories [Burgin, 2011]. In particular, it is possible to form the sequential composition of information directions.

Thus, if *I* is an information direction from a system *Q* to a system *R* and *J* is an information direction from a system *R* to a system *T*, then it is possible to take the sequential composition $J \circ I$ of *I* and *J* as the sequential composition of corresponding information operators [Burgin, 2011; 2011a]. The sequential composition $J \circ I$ is an information direction from a system *Q* to a system *T*.

Definition 12. Information from a system *Q* for a system *R* is called an *adapted information direction* or *directed information with adaptation* when this information is transmitted.

Usually adapted information directions form a subspace in the space of all information directions because by Corollary 3, the set of is closed with respect to the operation of sequential composition.

Definition 13. Information from a system *Q* to a system *R* about a system *T* is called an *information direction in a context* or *directed information in a context* when this information is transmitted.

The *context* of an information direction adds additional (one or more) dimensions to this information direction. For instance, conceiving information directions as two-dimensional vectors, we can treat information directions in a context as three-dimensional vectors.

Definition 14. Information in a system *Q* intended to a system *R* is called a *potential information direction*.

Definition 15. Information in a system *Q* for a system *R* is called an *adapted potential information direction*.

To have potential information directions, a system needs memory although it can be a non-standard memory, which is very different from the memory of computers or people. For instance, it is possible to speak about memory of a planet, a star or even a black hole. Recently physicists suggested and theoretically established the, so-called, *Holographic Principle*. According to it, the description of a volume of space can be encoded on a boundary to the region.

Definition 16. Information in a system *Q* to a system *R* about a system *T* is called a *potential information direction in a context*.

Definition 17. Information in a system *Q* for a system *R* about a system *T* is called an *adapted potential information direction in a context*.

As in the case of actual information directions, context adds (one or more) dimensions to the space of potential information directions.

5. Conclusion: An information overflow

We have identified several important types of information and used them to characterize information dynamics in the context of social interaction. One of the typology applications is aimed at analysis of the current situation with information that circulates in society. Due to the technological progress, more and more information is stored on the web and thus, becomes available to more and more people. This is *information in* the World Wide Web. When such information comes to a user of the web, it is, as a rule, *information to* and not *information for* this user. Moreover, it is often hard to find *information for* and even to make a clear distinction between *information to* and not *information for* this user. This causes the information overflow.

One of the consequences of the information overflow is that getting more information in bits, people start getting less and less true knowledge. The reason is that the average information quality declines and myriads of low quality information pieces conceal high quality portions of information, which often becomes lost for those who need this information. For instance, very often information on the web is either unreliable or even intentionally deceptive and because users cannot find correct information hidden under megabytes of rotten information, they not only miss true knowledge but acquire false ideas, beliefs and opinions.

A way to eliminate or, at least, to decrease this information overflow is to develop efficient means of converting *information to* into *information for*. One of the proposals in achieving this goal is the semantic web [Berners-Lee, et al, 2001; Feigenbaum, et al, 2007]. However, the problem of creating the full-sized semantic web on a decent level of intelligence cannot be solved in a sufficient form without a relevant information theory oriented at semantic representation of and operation with information. The results of this paper pave the way for such a theory.

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