http://dx.doi.org/10.15414/isd2016.s9.01

Information as a base of information and communication technologies

Veronika Achimská[1], Katarína Kramárová[2]
University of Žilina[1, 2]
Faculty of Operation and Economics of Transport and Communications, Department of Communications
Univerzitná 8215/1, 010 26
Žilina, Slovakia
e-mail[1,2]: veronika.achimska@fpedas.uniza.sk, katarina.kramarova@fpedas.uniza.sk

Abstract
This article deals with an issue of information and measurement of its quantity. In the presented article fundamentals of the information theory will be presented. Marginally, authors will also be dealing with mathematical fundamentals of quantification of information and the attention will also be paid to some specifics of the rate of information. The main motive of the article is to clarify chosen specifics of the rate of information that will be shown on simple examples from educational practice. As a subject of quantification, statements regarding to the phenomenon of "Roll of the dice" will be used. Through application of well-known mathematical relations and conditions authors try readers to understand problems of the measurement of information and highlight its specifics in the group of commonly known rates. The conventional theory of information is supplemented by selected examples such a way that readers should understand basic principles of the theory of information.

Key words: *information, rate, quantification, statements*

JEL classification: *A33, C89, Z00*

1. Introduction

Nowadays, many authors deal with the issue of information and communication technologies (thereinafter “ICT”), but in this article we would like to highlight the essence of this modern concept. The basis of this concept is the information itself and possibilities of its transformation and transfer. Surely we all agree that ICT would not be here if in the human history, starting with the period far before Christ, there were no needs of human beings to communicate each other including communication and storing knowledges in information. Certain forms of "ICT" could also be identified in the history. They have passed through several development stages up to the current “face” – the information age, which is knows almost by everyone.

There are many different definitions of the term “ICT”. For instance Molnár (1993) and Štoffová (1998) define the ICT like as a technology (as computers, telecommunications, data transfer and organization) that is used to processing the information as well as its software and organizational arrangements. According to Smitek (1998), ICT represents methods, procedures, and form of collecting, storing, processing, verification, evaluation, selection, distribution and timely receipt of the necessary information in required format and quality. In a broader sense, this term also includes technology (hardware) and software resources, to ensure supporting and implementing of mentioned activities. Kolenička (1998) argues that ICT is a system of methods, programs, procedures, activities that realize the maximum utilization of close and distant sources through communication in computer networks in order to find the optimal solution of defined (given) problems or achieve goals or meet needs. [1]

In connection with the presented article, however we do not deal with the physical aspects of ICT, because the core of our concern will be just the abstract – non-physical side of ICT starting with the information itself.

http://dx.doi.org/10.15414/isd2016.s9.01

2. Information in the theory

There are many definitions of the term “information”. Although the initial understanding of the information appeared in the social sciences, the most heated and most prolific development of the perception of information has been taken in the context of information theory and cybernetics.

The basic concepts of information were laid by C.E. Shannon. He did not consider as the information any message, but only the message that was able to reduce the uncertainty of the receivers (recipients) of information. The uncertainty exists when there is a choice of several options, which is typical for almost any human activity, but also for cyber technology, for animate and inanimate nature, too. American mathematician Norbert Wiener (the founder of cybernetics) characterized the information as that part of report (announcement) respectively such report, which was headed from the source to the recipient, who needed it to perform its duties. He emphasized that such information had to contain something new – original and which was unknown to the recipient and able to expand its knowledge regarding the display of the objective reality and at the same time eliminate or at least reduce the degree of the receiver´s uncertainty of his conduct.

Information as the termis not typical just for the field of cybernetics. There are many theories that deal with the concept of information and which emphasize such kind of aspects of the information that are not typical for the cybernetics and that are not of its first importance. Mainly the semantic and pragmatic information theories should be mentioned. In the 60s of the last century different cybernetic variants of the theory of information value appeared which used game theory, theory of algorithms and theory of optimal management. The process of the development of the concept of information is still not finished and many new disciplines “create” new views on the concept of information. [4]

The development of the computer technology led to the emergence and development of new fields. In the 70s of the last century a new scientific discipline “the informatics”arose on the basis of Computer Science. The definition of the subject of informatics was specified at the International Congress in Japanin 1978. The areas related to the development, production, utilization, material and technical provision and organization of information processing, including industrial, economic, administrative, social, and political actions are the subject of informatics. Based on it the informatics explores laws of creation, processing, transmission, use, preservation and protection of information. The informatics is one of the most rapidly developing sciences. Knowledge from this discipline is immediately putted into practice and brings a significant economic effect. The process of collecting, processing, transmission and storage of information refers to as information process.[6]

But let us return back to the information and its merits. From the definitions mentioned above, we can therefore say that the information is a message that falls within one of the possible events from the set of existing phenomena, which reduced the recipient ignorance of this phenomenon. It is the idea expressed in the language (using the symbols) expressing the state of an object and its manner.

2.1 Understanding of the concept of information

Firstly, it is important to differentiate between the term “information” and the term “data”. Most people believe that the terms are interchangeable and have the same meaning. However, there is a strict difference between them. The term “data” can represent any character, text, words, number, pictures, sound, or video and, if not put into context, means little or nothing to

http://dx.doi.org/10.15414/isd2016.s9.01

a human. However, information is useful and usually formatted in a manner that allows it to be understood by a human. [3]

The data is each message regardless of whether it contains any information content or not. In other words we can say - whether a message is able to tell us something new or not. The data are messages that reflect some facts about processes or about elements of the real world. The data could be considered as letters, numbers, words, characters, or its combinations. All data have some information content. If the data do not give any new information to its receivers, the information content of such kind of data is zero. [6]

Based on this we can derive the relationship between the data and information – each single piece of information must be a datum, but not each datum must be a single piece of information with nonzero information content for its receiver. Sample of these differences is given in Table 1.

Table 1:Differences between the terms "information" and "data"

	Data	Information
Meaning	Data is raw, unorganized facts that need to be processed. Data can be something simple and seemingly random and useless until it is organized.	When data is processed, organized, structured or presented in a given context so as to make it useful, it is called information.
Example	Each student's test score is one piece of data.	The average score of a class or of the entire school is information that can be derived from the given data.
Etymology	"Data" comes from a singular Latin word, datum, which originally meant "something given." Its early usage dates back to the 1600s. Over time "data" has become the plural of datum.	"Information" is an older word that dates back to the 1300s and has Old French and Middle English origins. It has always referred to "the act of informing", usually in regard to education, instruction, or other knowledge communication.

Source: http://www.diffen.com/difference/Data_vs_Information[5]

From knowledge of terminological and content differences between the data and information, it is possible to determine two main characteristics of information:

1. Measurability (how much of information is in the message – the amount of the information).
2. Addressability (each information has its own receivers; concerning its content it may be characterized as relevant – useful or irrelevant – useless information).

Mainly the first characteristic of the information will be discussed in the paper in more details.

2.2 Measurement of information

Before the measurability as the specific feature of the information will be clarified, we need to find out firstly where the information is located. Statements are the common carriers of any information. We know that every statement is an indicative sentence with the sense to decide whether it is true or false. Remarkably the truth value of statement is unrelated to the amount of information contained in the statement. Subsequently, if we want to be able to measure the information, we need to define "rate of information". In general, a rate in mathematical terms is a function that each set of an appropriate system of subsets of the X set assigns a real number such that certain conditions are met, so called axioms of the rate. Axioms of the rate

http://dx.doi.org/10.15414/isd2016.s9.01

capture essential characteristics that are required from the function that expresses a size of the set. Some example for understanding of the concept of the rate is shown in Table 2 – commonly used rates.

Table 2: Commonly used rates

Subjects of measurement	Rate of the subjects	Measurement units
set	number of elements	pcs
distance	length	m, cm, mm
area	content	m^2, ha
space	volume	m^3, l
mass	weight	kg, g, t

Source: authors

The rate is the central concept of the theory of measure, which aims to study abstract structures, which allow mathematical study of the quantity concept. The term of the rate has many applications, especially in theory of integral, theory of probability as well as theory of information.

Let us consider a question what type of rate can we use for measuring of information as a subject of measurement. The answer was given by Claude E. Shannon in his theory. In a landmark paper written at Bell Labs in 1948, Shannon defined in mathematical terms what information is and how it can be transmitted in the face of noise.

From the mathematical requirements imply that the rate of information (ref. φ) is such representation of an appropriate structure of set (ε) that a positive real number is assigned to each element of this structure:

$$\varphi: \varepsilon \rightarrow \mathbf{R}^+$$

The rate of information (φ) is called the amount of information and the smallest measurement unit of this rate is a bit. From the definition we also know that 1 bit is the amount of information which is obtained from any message about one of two possible states which were both equally probable.

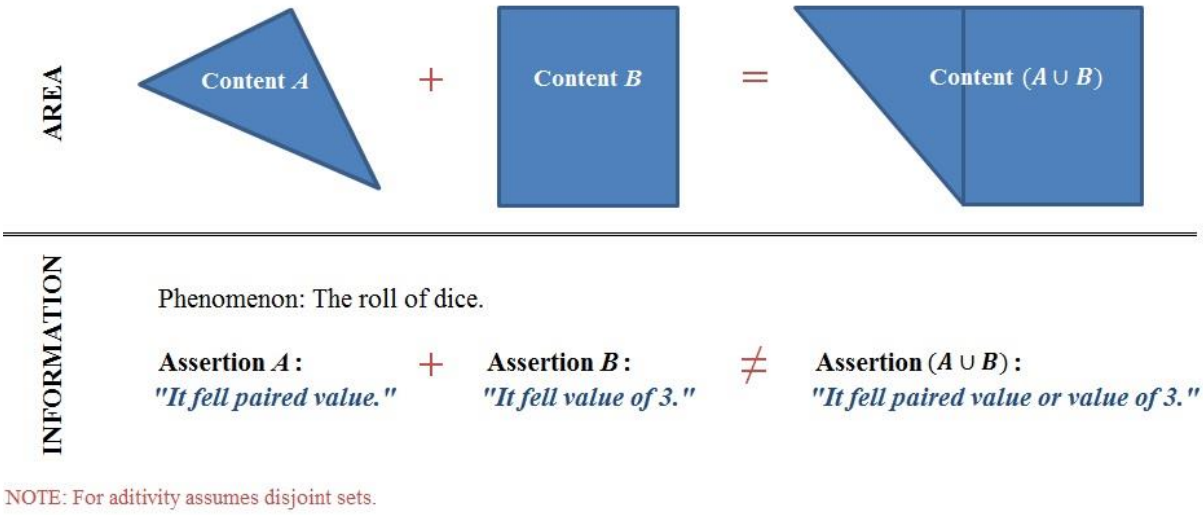
More detailed study of this rate shows unusual properties that are the essence of the problem addressed in this article. The amount of information is not common additive rate, as the standard rates (shown in Table 1). The problem of the additivity of the information is shown in the Figure 1.

2.3The amount of information

Shannon defined the quantity of information produced by a source (for example, the quantity in a message) by a formula similar to the equation that defines thermodynamic entropy in physics. In its most basic terms, Shannon's informational entropy is the number of binary digits required to encode a message. Today that sounds like a simple, even obvious way to define how much information is in a message. In 1948, at the very dawn of the information age, this digitizing of information of any sort was a revolutionary step. His paper may have been the first to use the word "bit", short for binary digit. [2]

http://dx.doi.org/10.15414/isd2016.s9.01

Figure 1:Non-additivity of information



Source: authors

As indicated in Figure 1, instead of use the addition operation (+) there is necessary for the amount of information to use other operation which keeps the original properties of additivity - so called ring operation (∘). Then we can say that information is pseudo-additive.

Thus, what mathematical relationsare true for the amount of information?

To quantify the information, which is obtain in the statements we can work with two fundamental mathematical relations resulting from:

- elementary definition of the information (by Shannon)

$$\varphi(A) = -\log_z P(A) \tag{1}$$

- required characteristics of the pseudoaditivity

$$\varphi(A) \circ \varphi(B) = -log_z(2^{-\varphi(A)} + 2^{-\varphi(B)}) \tag{2}$$

3. Quantification of information in practice

In this part of the article we attempt to apply a relatively difficult theory about the amount of information on a few simple examples of propositional experience. Through statements about selected phenomenon (convenient to illustrate the beauty of this theory is a phenomenon “Roll of the dice") we can point out the interesting and important features of information.

Let's start with an example no. 1a - Let us have two statements about the Roll of the dice:

A: "In the roll of the dice fell paired value.

B: "In the roll of the dice fell value of 6."

Intuitively we feel that the statement B provides more information than the statement A, however, the statement B is a subset of the statement A.

http://dx.doi.org/10.15414/isd2016.s9.01

Through application of known mathematical equation (1), we can also calculate our assumption:

$$\varphi(A) = -log_2 P(A) = -log_2 \frac{1}{2} = 1 \text{ (bit)}$$

$$\varphi(B) = -log_2 P(B) = -log_2 \frac{1}{6} \doteq 2{,}58 \text{ (bit)}; \qquad \varphi(B) > \varphi(A) \qquad (3)$$

On the same example (no. 1b) we can demonstrate that the amount of information φ is not an additive rate.We know that the following relationships hold true for the given statements:

- for the statements:$A \subset A \cup B$, $B \subset A \cup B$ (4)
- for probability of the statements: $P(A) \leq P(A \cup B)$, $P(B) \leq P(A \cup B)$ (5)

From relationships of probability of the statements (5), by compiling the system of inequalities and its dealing with appropriate mathematical editions, we get the statement:

$$\varphi(A) + \varphi(B) \geq 2 * \varphi(A \cup B) \geq 0 \quad \Rightarrow \quad \varphi(A) + \varphi(B) > \varphi(A \cup B) \qquad (6)$$

We have already shown that the classical additional operation (+), in the case of the amount of information, is not applicable. Let us therefore, in example no. 2, verify another mathematical equation (2), which should work in this case and let us try to quantify the amount of information of statements by the operation ring (∘) replacing the traditional operation plus (+) to count the amount of information.

However, it should be borne in mind this relationship can only be used for disjoint statements about the same phenomenon. Therefore let us edit the initial statement B as follows:

B: "In the roll of the dice fell value of 5."

Then we can pseudo-sum (by operation ring) the amount of information as follows:

$$\varphi(A) \circ \varphi(B) = -log_2\left(2^{-\varphi(A)} + 2^{-\varphi(B)}\right) = -log_2\left(2^{log_2 P(A)} + 2^{log_2 P(B)}\right) =$$
$$-log_2\left(P(A) + P(B)\right) = -log_2\left(\frac{2}{3}\right) \doteq 0{,}58 \text{ (bit)}$$

The operation ring substituted characteristics of thecommon census, which represents the unification of a set in the theory sets and in the level of statements it represents disjunction - logical statements operator "or”. Then we can create a new statement, which represents A union B, it leads to the statement C as follows:

C: "In the roll of the dicefellpaired value or value of 5."

By applying the equation (1) we can verify if the operation ring (2) is, in fact, the appropriate way to sum the amount of information:

$$\varphi(C) = -log_2 P(C) = -log_2 \frac{4}{6} \doteq 0{,}58 \text{ (bit)}$$

4. Results and discussion

In relation to the presented examples, we can draw conclusions and further discuss the rate of the information and its mathematical properties.

In the example no. 1a we have shown that the statement B, which appearsto be smaller, contains more information than the statement A. While the statement Bis a subset of the statement A. And therefore it is true that $B \subset A$ but $\varphi(B) > \varphi(A)$.

In the example no. 1b we have shown that the rate of the information is not additive because this argument is true: $\varphi(A) + \varphi(B) \neq \varphi(A \cup B)$.

Finally, in the example no. 2 we have verified,under the required conditions,the suitability of replacement operation for counting the amount of information called the operation ring by the formula (2).

As we can see from these examples, throwing the practical application of the known theory of the information on the appropriate statements it is possible to clarify more detailed concepts of the theory of information. Apart from these examples, there are a number of other interesting mathematical properties of the information that may be studieddeeper and enjoyed their excellence.

5. Conclusion

Nowadaysit is very modern to take an interest in IT and everything related to the new technical achievements. But there are only few people who are interested in the nature of functionality of this common part of our world, which is a shame in our opinion.
Referring to the mathematical basis of quantification of information we wanted to emphasize the specifics of rate of information, which is called the amount of information. In this case, a significant difference in comparison with the commonly used rates is a fact that the amount of information is not an additive rate. In spite of this fact, we have shown how it can be added (pseudo-added) an amount of information content of two disjoint statements.
The main purpose of the article was to stir the waters up in the ICT section with this article and get readers to deal with the abstract mathematical level of the information itself. We believe that our article inspires current fans ofinformation world to increase their interest in information and its exceptional mathematical base.

Acknowledgment
This article was generated by the project IV/KS/2016/1 Application of postal technological processes to the student experience.

Literature

[1] Burgerová J., Burger V.: *Systémové a aplikačné programy pre personálne počítače.* Access date: February 11, 2016, Available on: http://www.burger.sk/knizka/obsah/1.html

[2] Collins P.G. (2002, October 14): *Claude E. Shannon: Founder of Information Theory*. Scientific American, access date: February 15, 2016, Available on: http://www.scientificamerican.com/article/claude-e-shannon-founder/

[3] Computer Hope: *Software Q&A.* Access date: February 15, 2016, Available on: http://www.computerhope.com/issues/ch001629.htm

[4] Informatika – štúdium. *Súbor informácií z oblasti PC a IT technológií.* Access date: February 15, 2016, Available on: http://sk-informatika.studentske.cz/2008/09/defincia-informcie.html 1

[5] Milton, N. (2016, February 15). The explain video on Diffen page. Message posted to http://www.diffen.com/difference/Data_vs_Information

[6] Rosičová M.: *Informácie a údaje*. Access date: February 15, 2016, Available on: https://sites.google.com/site/rosicova/studijne-materialy/informacie

* Online full-text paper availability: doi:http://dx.doi.org/10.15414/isd2016.s9.01