Synergy of Mathematics, Informatics, Cybernetics and Computing

Review Paper

Dominika Crnjac Milić
Faculty of Electrical Engineering
Josip Juraj Strossmayer University of Osijek, Croatia
dominika.crnjac@etfos.hr

Abstract *– This paper will point out the relationship between mathematics, informatics, cybernetics and computing, the importance of which is indisputable in the modern world. We will try to give a definition of informatics as a link between the aforementioned disciplines. We will also draw attention to some methods used in informatics, mathematics, cybernetics and computing.*

Keywords: *informatics, mathematics, cybernetics, computing, information, system, entropy.*

1. INTRODUCTION

The existence of informatics, cybernetics and mathematics, and their importance in the modern world cannot be denied. Although this statement is evident in relation with the definition of informatics and cybernetics, experts applying informatics and cybernetics and even those who work in the fields of informatics and cybernetics, would hardly agree with that. A possible cause might be the rapid development of informatics and cybernetics in recent years, when informatics and cybernetics became established in practice much faster than theoretical foundations and methods were formed.

The statement in a very important book "Cybernetics" written by N. Wiener [1] points out similarities between control processes and the link in machines, human beings and many other living organisms. These processes refer to transfer, storage and processing of information, signals, communications or various data. The advent of informatics and cybernetics was conditioned by the needs in practice and the development of scientific disciplines that study control processes in various systems. The said disciplines represent a predecessor of the common theory on general regularities referring to control processes and transfer of information. This refers to regulation theory, statistical theory of information transfer, theory of optimal solutions, etc. Informatics, especially cybernetics, studies what is common to all control processes as well as the problem of forming a unique theory of these processes. It is not difficult to notice that all control processes are characterized by organized systems made up of control mechanisms and mechanisms under control, as in [2] and [3].

Cybernetics studies control processes from the information standpoint, so that it may be defined as a science of information acquisition, transfer, storage, processing and usage.

According to the methods it uses, cybernetics is a science that takes advantage of the mathematical apparatus and a comparative approach in the study of control processes.

2. THE CONCEPTS OF INFORMATION AND SYSTEM

Information and system are fundamental concepts in informatics. There are various definitions of the term information, but here we will mention one that is applicable to the needs of informatics. Information [3] is our perception of the outer world that is acceptable for living organisms or control machines.

Let us note some properties of information:

- due to the perception of the outer world, information improves knowledge of the recipient,
- information must be acceptable to the user,
- for the existence of information, there must be a sender and a recipient of information.

A question naturally arises as to whether information is of objective or subjective character. It is not difficult to conclude that the information content is objective and that its value is subjective, since it depends on the information recipient. This problem can be studied only if we are able to measure information. For that purpose, in 1948, Claude Shannon proposed a degree of uncertainty from the recipient's viewpoint for the measure of information [3].

The greater the value of information, the less its expectancy, i.e. the less the value of information, the greater its expectancy. To measure information, it is necessary to introduce a measuring unit called a bit. The value of one bit has information about the event that may or may not take place with the same probability of 0.5. A shortcoming of such approach to information measurement is the need for a greater number of repetitions necessary to assess the occurrence or non-occurrence of the event. The consequence of that is a narrow scope of application of a probabilistic-statistical approach to the development of information theory. This approach is used in a wide range of applications in the study of communication systems. Nowadays there are various attempts trying to create other approaches to information theory; however, for the time being, Shannon's approach seems to be most constructive.

For achieving awareness, we will mention two new approaches to information theory.

From an informatics point of view, thesaurus theory of information is significant. Thesaurus theory of information implies a set of information a recipient has at his/her disposal at the moment communication is received. A communication contains information new to the recipient if his/her thesaurus has the following properties:

- it has a procedure for decoding a communication, so that the recipient can understand the meaning of the communication,
- the communication carries the information that is not part of the thesaurus, i.e. it expands the recipient's thesaurus.

What makes the development of this approach to information theory difficult is quantitative assessment of the size of thesaurus.

Another approach to information theory refers to the study of the recipient's behavior after receiving the communication. In this case, the information value in the communication is directly related to a change in the recipient's behavior after receiving the communication. If the recipient does not change his/her behavior after receiving the communication, the communication itself does not contain any information for the recipient. We can notice that information theory has been constantly developing. New approaches should be searched for and the existing approaches should be developed further in this field.

In addition to information, the notion of system also plays an important role in informatics. The word system refers to an organized set of objects by means of which a certain goal is achieved. Nowadays we encounter various types of systems such as economic, social, technical, information, etc. These are the systems in which the flow of information, as well as information storage and processing possibilities are important.

According to the aforementioned, informatics can be defined as a science that studies an information systems in general.

At the beginning, man was collecting information from the outer world, stored and processed them to the extent his intellect would allow him. A huge step forward in the development of civilization was done when letters were introduced, what enabled storage and transfer of information.

The essence of a selective concept implies that an arbitrary signal, arbitrary information independent of the contents and meaning can be understood as a choice between two or more values provided with probabilities. This concept enables the approach to all processes with the same measure and the same stochastic apparatus. Based upon the aforementioned, there emerged an idea of a general theory of organizational and control relations in systems Wiener named cybernetics.

The amount of information, a multitude of sources Wiener identified with negative entropy [4], becomes one of the most fundamental characteristics of natural phenomena.

In this way, cybernetics is interpreted as organizational theory, theory of the fight against chaos, against the increase of entropy. In other words, Wiener relates cybernetics to statistical physics and the fight against the increase of entropy.

Cybernetics undoubtedly moves around the notion of information, although control theory is a broader term in comparison with today's information theory or a general theory of relationships. The general theory of relationships is logically founded and developed, restriction of control theory to the theory of relationships does not imply their uniformity. It has to be borne in mind that transmission of information and information processing are two different issues.

Let us note that zero entropy corresponds to complete information, every entropy conforms to vanishing information.

Introduction of computers enabled organization of information systems in which information are collected, stored and processed. From the viewpoint of the flow of information, computer is in the same relation as man with respect to the environment.

Since entropy and uncertainty have the same mathematical expression, they could be considered synonyms.

3. MATHEMATICS AND INFORMATICS

There is a question whether informatics is a separate discipline or whether it is a building block of mathematics. To get a clear attitude about that question it is necessary to know important properties of both mathematics and informatics. It is known that mathematics belongs to the oldest scientific discipline that studies abstract objects and their mutual relations, i.e. abstract

systems. The property of mathematics worth paying attention to is applicability. We may say that mathematical approaches and mathematical methods are applied to all other sciences.

It is also applied to studying phenomena of discrete and continuous nature, as well as phenomena of deterministic and stochastic character. We may conclude that two important, at first sight contradictory, properties of mathematics are abstractness and applicability.

It is necessary to note that a transition to the mathematical model means separation from the physical nature of an object. The mathematical model retains only the information content of the object. Since information contents are studied in informatics, it becomes clear that there exists a natural bond between mathematics and informatics. Abstractness of informatics is evident since it includes:

- the choice of important properties of objects or phenomena in the real world and ignorance of irrelevant differences,
- the choice of the set of symbols for presentation of an abstract object.

Let us note that levels of abstractness in mathematics and informatics differ. The level of abstractness in mathematics can be very high implying non-existence of any practical interpretation, while in informatics abstractness has practical interpretation.

We may conclude that there is a major link between mathematics and informatics. These are disciplines with the same basic properties and interactions that positively affect the development of both disciplines. Thanks to informatics, mathematical approaches and mathematical methods established themselves in many other disciplines. Application of computers to the analysis of mathematical models releases scientists (researchers) from painstaking calculation enabling them at the same time to be involved in creative work of searching for mathematical models.

To set up a mathematical model we should necessarily be acquainted with both the field of application and the field of mathematics. The field of application may be any scientific discipline, and the mathematical model may be deterministic, statistical or stochastic. To introduce a mathematical model into the program, it is necessary to familiar with mathematical methods by means of which it is possible to explicitly express unknown values in the model by knowing programming. Knowing numerical methods, algorithmization and writing a program in a programming language, are of great importance. In order to be able to implement the program it is necessary to know the computer capacity and modes of communication between a user and a computer. It may be stated that informatics significantly contributes to the applicability of mathematics.

It is important to stress the difference between computer and man, i.e. computers are programmed, and people work creatively. Computers outperform people with respect to the capacity of information storage, speed and processing accuracy.

The aforementioned makes a computer a complex machine whose assembling, programming ([5] and [6]) and application result in a special scientific discipline, i.e. computing [7].

4. CONCLUSION

This paper points out the importance of informatics, mathematics, cybernetics and computing in the modern world. It offers guidelines for a definition of informatics, since many experts who apply informatics, even those who work in the field of informatics, do not agree on the definition of informatics. The paper also indicates reasons for discrepancies in relation with the definition of informatics, since here we deal with a natural consequence of the rapid development of informatics in recent years. This development refers to the period in which informatics became established in practice much faster than theoretical foundations and methods were formed.

REFERENCES

[1] N. Wiener, Cybernetics: or Control and Communication in the Animal and the Machine, 2nd Edition, MIT Press, 1965.

[2] L.A. Rastrigin, Kibernetika i poznanice, Zinatie, Riga, 1978.

[3] D.C. Johnson, J.D. Tinsley, Informatics and Mathematics in Secondary Schools, North Holland, 1997.

[4] Ž. Pauše, Vjerojatnost, informacija, stohastički procesi, Školska knjiga, Zagreb, 1978.

[5] M.E Henderson, W.L Miranker, Synergy in Parallel Algorithms, Parallel Computing, Vol. 11, Issue 1, 1989, pp. 17-35.

[6] V.G. Kaburlasos, C.C. Marinagi, V.Th. Tsoukalas, Personalized Multi-student Improvement Based on Bayesian Cybernetics, Computers & Education, Vol. 51, Issue 4, 2008, pp. 1430-1449.

[7] O.J. Dahl, E.W. Dijkstra, C.A. Hoare, Structured Programming, Academic Press, London, 1972.