Zdzisław Pawlak Commemorating His Life and Work*

Zdzisław Pawlak will be remembered as a great human being with exceptional humility, wit and kindness as well as an extraordinarily innovative researcher with exceptional stature. His research contributions have had far-reaching implications inasmuch as his works are fundamental in establishing new perspectives for scientific research in a wide spectrum of fields.

Professor Pawlak's most widely recognized contribution is his brilliant approach to classifying objects with their attributes (features) and his introduction of approximation spaces, which establish the foundations of granular computing and provide frameworks for perception and knowledge discovery in many areas.

Zdzisław Pawlak was born on 10 November 1926 in Łódź, 130 km south-west from Warsaw, Poland[1]. In 1947, Pawlak began his studies in the Faculty of Electrical Engineering at Łódź University of Technology, and in 1949 continued his studies in the Telecommunication Faculty at Warsaw University of Technology. In 1950, he presented in Poland the first project of a computer called GAM 1. He completed his M.Sc. in Telecommunication Engineering in 1951. His publication in 1956 on a new method for random number generation was the first publication abroad in informatics by a researcher from Poland[2]. In 1958, Pawlak completed his doctoral degree from the Institute of Fundamental Technological Research at the Polish Academy of Science with a Thesis on Applications of Graph Theory to Decoder Synthesis. During 1957-1959, Pawlak was also a member of a research team that constructed one of the first computers in Poland called UMC 1. The original arithmetic of this computer with the base "-2" was due to Pawlak. He received his habilitation from the Institute of Mathematics at the Polish Academy of Sciences in 1963. In his habilitation entitled Organization of Address-Less Machines, Pawlak proposed and investigated parenthesis-free languages, a generalization of polish notation introduced by Jan Łukasiewicz[3].

During succeeding years, Pawlak also worked at the Institute of Mathematics at Warsaw University and, in 1965, introduced the foundations for modeling DNA and what has come to be known as molecular computing[4]. He was searching

* Professor Zdzisław Pawlak, Member of the Polish Academy of Sciences, passed away on 7 April 2006.

[1] Wikipedia summary of the life and work of Z. Pawlak: `http://pl.wikipedia.org/wiki/Zdzislaw_Pawlak`

[2] Pawlak, Z.: Flip Flop as Generator of Random Binary Digits. Mathematical Tables and Other Aids to Computation 20(53) (1956) 28-30.

[3] Pawlak, Z.: Organization of Address-Less Computers Working in Parenthesis Notation. Zeitschrift für Mathematische Logik und Grundlagen der Mathematik 3 (1965) 243-262; Pawlak, Z.: Organization of Address Less Computers. Polish Scientific Publisher, Warsaw (1965) (the book is in Polish).

[4] Pawlak, Z.: Grammar and Mathematics. (in Polish), PZWS, Warsaw (1965); Gheorghe, M., Mitrana, V.: A formal Language-Based Approach in Biology. Comparative and Functional Genomics 5(1) (2004) 91-94.

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for grammars generating compound biological structures from simpler ones, e.g., proteins from amino acids. He proposed a generalization of traditional grammars used in formal language theory. For example, he considered the construction of mosaics on a plane from some elementary mosaics by using some production rules for the composition. He also presented a language for linear representation of mosaic structures. It was thought that by introducing such grammars, one might better understand protein structure and the processes of their synthesis. Such grammars would give birth to real-life languages to characterize the development of living organisms. Pawlak was interested in developing a formal model of *deoxyribonucleic acid* (DNA), and he proposed a formal model for the genetic code discovered by Crick and Watson. Pawlak's model is regarded by many as the first formal model of DNA. This work on DNA has been cited by others.

Zdzisław Pawlak also proposed a new formal model of a computing machine known as the *Pawlak machine*[5] that is different from the Turing machine and from the von Neumann machine. In 1973, he introduced knowledge representation systems as part of his work on the mathematical foundations of information retrieval [6]. During the early 1980s, he was the head of a research group at the Institute of Computer Science at the Polish Academy of Sciences, where he introduced rough sets and the idea of classifying objects by means of their attributes[7]. Rough set theory has its roots in Zdzisław Pawlak's research on knowledge representation systems during the early 1970s. Rather than attempt exact classification of objects with attributes (features), Pawlak considered an approach to solving the object classification problem in a number of novel ways. First, in 1973, he introduced knowledge representation systems. Then, in 1981,

[5] Pawlak, Z.: On the Notion of a Computer. Logic, Methodology and Philosophy of Science 12, North Holland, Amsterdam (1968) 225-242; Pawlak, Z.: Theory of Digital Computers. Mathematical Machines 10 (1969) 4-31; Pawlak, Z.: A Mathematical Model of Digital Computers. Automatentheorie und Formale Sprachen 1973: 16-22; Pawlak, Z., Rozenberg, G., Savitch, W. J.: Programs for Instruction Machines. Information and Control 41(1) (1979) 9-28.

[6] Pawlak, Z.: Mathematical Foundations of Information Retrieval. Proceedings of Symposium of Mathematical Foundations of Computer Science, September 3-8, 1973, High Tartras, 135-136; Pawlak, Z.: Mathematical Foundations of Information Retrieval. Computation Center, Polish Academy of Sciences, Research Report CC PAS Report 101 (1973); Pawlak, Z.: Information Systems Theoretical Foundations. Information Systems 6(3) (1981) 205-218; Pawlak, Z.: Information Systems: Theoretical Foundations. WNT, Warsaw (1983) (the book in Polish); Marek, W., Pawlak, Z.: Information Storage and Retrieval Systems: Mathematical Foundations. Theoretical Computer Science 1 (1976) 331-354.

[7] Pawlak, Z.: Rough Sets. Research Report PAS 431, Institute of Computer Science, Polish Academy of Sciences (1981); Pawlak, Z.: Classification of Objects by Means of Attributes. Research Report PAS 429, Institute of Computer Science, Polish Academy of Sciences, ISSN 138-0648, January (1981); Pawlak, Z.: Rough Sets. International J. Comp. Inform. Science 11 (1982) 341-356; Konrad, E., Orłowska, E., Pawlak, Z.: On Approximate Concept Learning. Report 81-07, Fachbereich Informatik, TU Berlin, Berlin 1981; short version in: Collected Talks, European Conference on Artificial Intelligence 11/5, Orsay/Paris (1982) 17-19.

he introduced approximate descriptions of objects and considered knowledge representation systems in the context of upper and lower classification of objects relative to their attribute values. During the succeeding years, Pawlak refined and amplified the foundations of rough sets and their applications[8] and nurtured worldwide research in rough sets that has led to over 4000 publications[9]. The consequences of this approach to the classification of objects relative to their feature values have been quite remarkable and far-reaching. The work on knowledge representation systems and the notion of elementary sets have profound implications when one considers the problem of approximate reasoning and concept approximation.

Zdzisław Pawlak also invented a new approach to conflict analysis[10].

He has published over 220 scientific papers and supervised over 30 PhD Theses.

For many years, Zdzisław Pawlak had an intense interest in philosophy, especially relative to the connections between rough sets and other forms of sets. It was his venerable habit to point to connections between his own work in rough sets and the works of others in philosophy and mathematics. This is especially true relative to two cardinal notions, namely, sets and vagueness. For the notion of a set, Pawlak calls attention to works by Georg Cantor, Gottlob Frege and Bertrand Russell. Pawlak points out that the notion of a set is not only fundamental for the whole of mathematics but also for natural language, where it is commonplace to speak in terms of collections of such things as books, paintings, people, and their vague properties. In his reflections on structured objects, he points to the work on mereology by Stanisław Leśniewski, where the relation *being a part* replaces the membership relation $\in$[11]. For many years, Pawlak also was interested in vagueness and Gottlob Frege's notion of the boundary of a concept[12]. For Frege, the definition of a concept must unambiguously determine whether or not an object falls under the concept. For a concept without a sharp boundary, one is faced with the problem of determining how close an object must be before it can be said to belong to a concept. Zdzisław Pawlak also points out that mathematics must use crisp, not vague concepts. Hence, mathematics makes

[8] see, e.g., Pawlak, Z.: Rough Sets – Theoretical Aspects of Reasoning about Data. Kluwer Academic Publishers, Dordrecht (1991).

[9] see, e.g., Rough Set Database System, `http://rsds.wsiz.rzeszow.pl/pomoc9.html`

[10] Pawlak, Z.: On Conflicts. International Journal of Man Machine Studies 21 (1984) 127-134; Pawlak, Z.: Anatomy of Conflict. Bulletin of the European Association for Theoretical Computer Science 50 (1993) 234-247; Pawlak, Z.: An Inquiry into Anatomy of Conflicts. Journal of Information Sciences 109 (1998) 65-78; Pawlak, Z.: On Conflicts. Polish Sci. Publ., Warsaw (1987) (the book is in Polish).

[11] In 1996, the study of Leśniewski's work has led to rough mereology and the relation *being a part to a degree* (see, e.g., Polkowski, L., Skowron, A.: Rough Mereology: A New Paradigm for Approximate Reasoning. International J. of Approximate Reasoning 15(4) (1996) 333-365).

[12] Frege, G.: Grundgesetzen der Arithmetik, vol. II. Verlag von Hermann Pohle, Jena (1903).

1.1: Treeline Painting by Pawlak

1.2: 1999 Watercape by Pawlak

Fig. 1. Paintings by Zdzisław Pawlak

it possible to reason precisely about approximations of vague concepts. These approximations are temporal and subjective.

Starting in the early 1950s and continuing throughout his life, Zdzisław Pawlak painted the places he visited, especially landscapes and waterscapes of the places he visited in Poland and other parts of the world. A common motif in Pawlak's paintings is the somewhat indefinite separation between objects such as the outer edges of trees and sky (see Fig. 1.1), the outer edges of tree shadows reflected in water and the water itself, and the separation between water and the surrounding land (see Fig. 1.2).

In more recent years, he wrote poems, which are remarkably succinct and very close to his interest in painting. Remarkably, one can find in his theoretical work on rough sets as well as in molecular computing, painting and poetry a common thread, namely, his interest in the border regions of objects that are delineated by considering the attributes (features) of an object.

Professor Zdzisław Pawlak was with us only for a short time and, yet, when we look back at his accomplishments, we realize how greatly he has influenced us with his generous spirit and creative work in many areas such as approximate reasoning, intelligent systems research, computing models, mathematics (especially, rough set theory), molecular computing, pattern recognition, philosophy, art, and poetry.

Zdzisław Pawlak gave generously of his time and energy to help others. His spirit and insights have influenced many researchers worldwide. During his life, he manifested an extraordinary talent for inspiring his students and colleagues as well as many others outside his immediate circle[13].

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[13] The authors wish to thank *all* colleagues who, at various times in the past, have contributed information that has made it possible to write this article.