Chapter 1
Professor Zdzisław Pawlak (1926-2006): Founder of the Polish School of Artificial Intelligence

Andrzej Skowron, Mihir Kr. Chakraborty, Jerzy Grzymała-Busse, Victor Marek, Sankar K. Pal, James F. Peters, Dominik Ślęzak, Roman Słowiński, Shusaku Tsumoto, Alicja Wakulicz-Deja, and Guoyin Wang

He was not just a great scientist – he was also a great human being.
– Lotfi A. Zadeh, April 2006

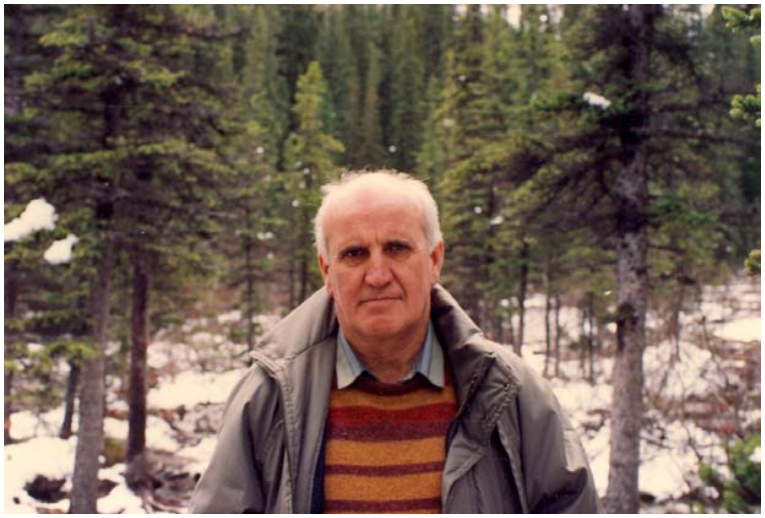


Fig. 1.1: Zdzisław Pawlak.

Corresponding author: Andrzej Skowron, Institute of Mathematics, Warsaw University Banacha 2, 02-097 Warsaw, Poland, e-mail: skowron@mimuw.edu.pl

1.1 Introduction

This chapter is dedicated to the memory of Professor Zdzisław Pawlak, founder of the Polish school of Artificial Intelligence and one of the pioneers in Computer Engineering and Computer Science with worldwide influence.

To capture the spirit of Professor Pawlak's creative genius, this chapter contains testimonies of many collaborators, colleagues and friends pointing to Professor's scientific achievements and his personal qualities. In short, we present Professor Pawlak as a truly great scientist, teacher and human being.

1.2 Biography [51]

Zdzisław Ignacy Pawlak was born on 10 November 1926 in Łódź, where he also finished primary school in 1939. During the German occupation of Poland, like many Poles, he was a slave-laborer and was forced to work for Siemens company. After WW II, in 1946, he passed his high school exams as an extern and, in 1947, started his studies at the Electrical Engineering Faculty of the Łódź University of Technology. In 1949, he transferred to the Electrical Faculty (the Faculty of Telecommunication between 1951–1966, the Faculty of Electronics and Information Technology at present) at the Technical University of Warsaw (now the Warsaw University of Technology). He received his engineering degree in Telecommunications and Master of Science degree in Radio Engineering in 1951, presenting the diploma thesis entitled *A clock for the electronic computing machine*, prepared under supervision of Romuald Marczyński.

After graduation, he worked as a junior member of the research staff at the Mathematical Institute of Polish Academy of Sciences (PAS) (now Institute of Mathematics of Polish Academy of Sciences (PAS)) until 1957. Between 1957–1959 he worked at the Technical University of Warsaw, where he took part in designing the first Polish computer. In effect, one of the first computing machines in Poland was built under his supervision. In 1959, he returned to the Institute of Mathematics of PAS where he worked as an assistant professor from 1959 to 1963.

He received his doctoral degree in 1958 (at the time called *candidate of technical sciences*) at the Institute of Fundamental Technological Research of PAS presenting the doctoral thesis entitled *Application of Graph Theory to the Decoder Synthesis*. The dissertation was supervised by Professor Krystyn Bochenek.

Professor Pawlak received his postdoctoral degree (habilitation, Dr. Sci.) in Mathematics at the Institute of Mathematics of PAS in 1963 for the dissertation entitled *Organization of Address-less Machines*. From 1963 until 1969, he worked at the Institute of Mathematics of the Warsaw University.

In 1971, he was promoted to an Associate Professor at Institute of Mathematics of PAS. Between 1971 and 1979, Professor Pawlak was the Deputy Director for Science at the Computer Center of PAS, and later, after the institute's renaming in 1976, of the Institute of Computer Science of PAS. In 1978, he was promoted to a

(full) Professor in the Institute of Computer Science of PAS in Warsaw. In 1983, he was elected a corresponding member of PAS, and later, in 1991, he became a full member of the Polish Academy of Sciences. From 1979 to 1986, he was the director of the Institute of Informatics of the Silesian University of Technology. Starting from 1985, he worked at the Institute of Theoretical and Applied Informatics of PAS in Gliwice. In 1998, he also worked at the University of Applied Computer Science and Management in Warsaw. Between 1989 and 1996, he was the director of the Institute of Computer Science of the Warsaw University of Technology.

In 1950, Professor Pawlak developed the first generation computer GAM-1 at the Group of Computing Machines (GAM) at the State Institute of Mathematics in Warsaw. However, that machine was never used for practical applications. In 1951, Zdzisław Pawlak came up with a new way to generate random numbers, which was published in the prestigious *Mathematical Tables and Other Aids to Computation* journal (now called *Mathematics of Computation*), the oldest journal devoted to computation [17]. It was the first ever Polish computer science work published abroad. Later, he suggested a new method for representing numbers in the positional numerical system with a negative radix -2 (so called -2 system). Based on this technique and horizontal microprogramming, with Professor Pawlak's project and supervision, a computing machine UMC-1 was built at the Warsaw University of Technology. Later, Professor Pawlak was studying many aspects of computer science, including computational linguistics, automata theory, automated theorem proving, and information retrieval. One of the most interesting achievements of that period was a new formal model of computing machine, different from Turing's machine and Rabin-Scott's finite automata. That model gained a lot of attention worldwide and was called Pawlak machine in the literature. Another important accomplishment was creating the first mathematical model of Crick and Watson's DNA encoding. Pawlak also developed an original approach to the information retrieval. He also proposed a new mathematical approach to the conflict analysis, which has an important applications in psychology, economy and politics.

Professor Pawlak's most important discovery was his invention of rough set theory in 1982, which gained vast popularity throughout the World. More than 5000 English-language publications about Pawlak's theory and its applications have been published so far, including several books.

Many international conferences, mainly in the USA, Canada, China, India, Japan and Europe were organised to discuss and develop Professor Pawlak's work.

At those conferences he gave lectures, among other subjects, in mathematical logic, mathematical foundations of computer science, organization of computing machines, mathematical linguistics and rough set theory. He was frequently invited as a Visiting Professor to many universities in the USA, Canada and Europe, including Philosophy Department at Stanford University (1965).

Professor Pawlak received many honours and awards acknowledging his achievements as one of the main animators of scientific life in Poland. His work was recognized on the national level by the Polish government, including Polish National Science Award in 1973, Polish Knight's Cross of the Order of Polonia Restituta in 1984, Polish Mathematical Society Steinhaus Prize for achievements in applications

of Mathematics for 1989 and Polish Officer's Cross of the Order Polonia Restituta in 1999.

Professor Pawlak was a member and officer of many scientific organizations, active in various periods of time in over 30 governing councils (including being the president of a number of those). In his native Poland, he was the president of the National Central Committee for Scientific Titles and Degrees (CKK) between 1975 and 1988 (mathematical and technical sections) [1], member of the Computer Science Committee of PAS, the Committee of Cooperation of Academies of Sciences of the Socialist Countries on Computational Technology (1971 - 1979), the State Committee for Scientific Research (1994 - 2000), the Central Committee for Scientific Titles and Degrees (2000 - 2006), the Polish Mathematical Society and the Polish Semiotic Society (vice-president, 1990 - 1996). He served on several editorial boards of scientific journals, both foreign and national. He served as the deputy editor-in-chief of the Bulletin of PAS. On his initiative the journal Fundamenta Informaticae was created. For many years, he served as the deputy editor-in-chief of Fundamenta Informaticae. He published over two hundred articles and a number of books. Professor Pawlak supervised thirty doctoral dissertations. We quote all these facts to show the amount of his energy and enthusiasm devoted to promotion of scientific research, education of young researchers and their supervision.

Professor Pawlak loved to spend time with family in nature surrounding (see Figure 1.2). So many visitors and friends from all over the world were always very welcome at home of Professor Pawlak by his wife Danuta.

Fig. 1.2: Professor Zdzisław Pawlak with wife Danuta and daughter Dorota (picture taken in 1950s).

[1] This committee was responsible for the scientific evaluation of candidates applying for D. Sci. (habilitation) degree and Professor title and recommending the final decision.

1.3 From the Clock to the Pseudo-random Number Generator

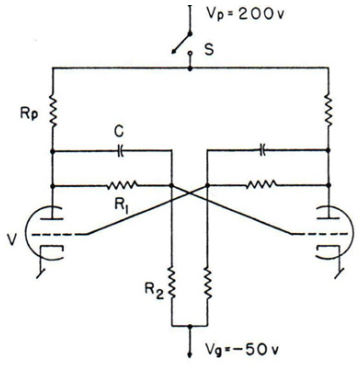
As it was mentioned before, Zdzisław Pawlak got his engineer's degree in Telecommunications and Master of Science degree (in radio engineering) in 1951, presenting the diploma thesis *A clock to the electronic computing machine*, supervised by Romuald Marczyński. An interesting story is connected with this work, which was told by the Professor at the conference dinner in Jabłonna Palace, near Warsaw, during the The First International Conference on Rough Sets and Current Trends in Computing (RSCTC) in 1998 [42] (see the picture below).

Fig. 1.3: Meeting during the dinner at the First International Conference on Rough Sets and Current Trends in Computing (RSCTC 1998) in the Jabłonna Palace (near Warsaw): Professor Zdzisław Pawlak is describing how the clock from his master's thesis was transformed into the pseudo-random number generator.

It turned out that the clock designed in his master's thesis, is hardly stable. Then, Zdzisław Pawlak came into conclusion that the design may be modified and used to create a pseudo-random number generator. All that became an inspiration for the work on Flip-flop as a generator of random binary digits, published in 1956 in the *Mathematical Tables and Other Aids to Computation* [17].

Many years later, Professor Pawlak visited one of the American institutes, where he was proudly presented with a fine quality pseudo-random number generator. He was also told that it was based on the idea of a Polish scientist. When he asked about the name of that scientist, he got the reply, *Pawlak*[2].

[2] See (video) interview with Professor Pawlak at `www.atvn.pl/index_sub_page.php?atvn=archiwum/index&title=ARCHIWUM&icm=edit_lista&graf=`



$R_p = 10\ K\Omega$
$R_1 = 160\ K\Omega$
$R_2 = 50\ K\Omega$
$C = 50\ \mu\mu fd$
$V = \frac{1}{2}$ 6SN7

FIG. 1.

In this way we may obtain a finite random series of A and B which are statistically independent. One series produced by the aid of a flip-flop is given below:

AABAABBABBABBBABBAABABABBABAABABABBAA
BABABBBBBBBBBABBBABAABBB.

Let $\{Y_k\}$ be the sequence of k pairs of elements of $\{X_{2k}\}$ such that $Y_i = X_{2i-1}, X_{2i}$, where $1 \leq i \leq k$. Omitting in $\{Y_k\}$ all elements of the form AA and BB we obtain a third sequence whose elements are the pairs AB and BA only, denoted in the following by 0 and 1 respectively.

Let $p_j(\mathrm{A})$ and $p_j(\mathrm{B})$ denote probabilities that j-th switching on of contact S set flip-flop in state A or B respectively and suppose that $p_j(\mathrm{A})$ and $p_j(\mathrm{B})$ are asymmetric, say $p_j(\mathrm{A}) > p_j(\mathrm{B})$. Supposing that the flip-flop does not change its properties during two successive switchings, we may write

(1) $$p_{2i-1}(\mathrm{A}) = p_{2i}(\mathrm{A})$$

(2) $$p_{2i-1}(\mathrm{B}) = p_{2i}(\mathrm{B}).$$

From 1 and 2 we have

(3) $$p_{2i-1}(\mathrm{A}) \cdot p_{2i}(\mathrm{B}) = p_{2i-1}(\mathrm{B}) \cdot p_{2i}(\mathrm{A}).$$

Because

(4) $$p_{2i-1}(\mathrm{A}) \cdot p_{2i}(\mathrm{B}) = p_i(0)$$

Fig. 1.4: Fragment of the work *Flip-flop as generator of random binary digits*.

1.4 Engineer and Mathematician

As an engineer, Professor Pawlak treated language of Mathematics as a tool to formulate his ideas accurately. He was convinced that Computer Science must be founded on Mathematics. He was one of the pioneers of research direction called

Foundations of Computer Science and initiated a conference with that name. Undoubtedly, his attitude was influenced by years of his work at the Mathematical Institute of PAS in Warsaw. Professor Pawlak's own words, delivered at the Poznań University of Technology, during the ceremony of awarding him a honorary doctoral degree, pictures that period best. A short fragment of his speech is presented below [32]:

My first experience of scientific work occurred in 1951 at the State Mathematical Institute (at present, The Institute of Mathematics of PAS), where, after graduating from the Warsaw University of Technology, a group of scientists headed by engineer Romuald Marczyński was building the first Polish computer. This group was called "Mathematical Apparatuses Group" (GAM). Dealing with a totally new area of science, both in Poland and all over the World, I found myself in an unusual situation for a fresh graduate of the University of Technology. At that time, the only existing computer (as we know them now) was located at the Cambridge University. We, the builders, had a complete lack of knowledge, literature and, the most important, skilled 'masters' that would be able to lead our group of inexperienced, young scientists. There was a large group of outstanding, world renown mathematicians working at the Institute of Mathematics of PAS including Professors Karol Borsuk, Wacław Sierpiński, Kazimierz Kuratowski, Andrzej Mostowski, Roman Sikorski, Jerzy Łoś, Stanisław Mazur, Andrzej Grzegorczyk, and others. However, the area of computing machines, which is how computers were then called, was of no interest to them. Work at the Institute of Mathematics gave me an opportunity to interact with many great mathematicians, even from the outside of the Institute, for instance Professors Helena Rasiowa, Kazimierz Ajdukiewicz, Hugo Steinhaus, Klemens Szaniawski, and others. Moreover, thanks to the work at the Institute, I had the opportunity to meet some of the greatest mathematicians of the 20th century, including Alfred Tarski, Stanisław Ulam, Samuel Eilenberg, Alonzo Church, Leon Henkin, Dana Scott, Laszlo Kalmar, Alfréd Rényi, Rózsa Péter, Andriej Kołmogorow, Borys Trachtenbrot, Borys Gniedenko, Andriej Markow, Andriej Tichonow, and others. These contacts had no direct impact on my scientific development but the atmosphere dominating the Institute and daily contacts with eminent scholars indirectly influenced my personal scientific interests a lot. In the case of dealing with our team's specific problems, everybody had to find his own solution. Actually, this had some advantages, because it left us a significant area of independence, but today, I tend to think that disadvantages of that situation overwhelmed its positive sides. It is not the right time to develop the topic, but taking all that into consideration, that situation had significant effects on my personal development as a researcher with both advantages and disadvantages.

After a short period of time, the logician Henryk Greniewski became the head of GAM. He was a polite and kind-hearted man with a great personality. I owe him my first contacts with scientific issues. He was the first one to organise a seminar on Boolean algebras and their usage in synthesis of digital systems, which was a mysterious topic for me at the time. He always had a kind advice for me and payed attention to my problems, not necessarily connected to science. Without hesitation he played a significant role in my scientific development. I organised my first seminar later with my friend Dr Andrzej Ehrenfeucht, an eminent mathematician and a man of many interests, not only limited to mathematics. Our meetings were concerned with computers, algorithms and logic, which definitely broadened both my knowledge and scientific horizons.

1.5 Computation Models, Rough Sets and Artificial Intelligence

It is natural to divide Professor Pawlak's scientific work into a number of stages. The first of these is his work on first Polish digital computer in the 1950s. During this period, Professor Pawlak worked on organization of digital machines and the logic of operation of digital systems. Coming up with a new method of representing numbers in the positional numeral system with a negative radix (-2 *system*) was a significant achievement of that period. This method was used to implement arithmetic-logic operations in the arithmetic operations unit of an experimental computing machine UMC-1, built under Zdzisław Pawlak's supervision at the Warsaw University of Technology. In the 1960s, a significant Computer Science research was concerned with the logic of digital machines. Automata theory was evolving especially fast. At the time Professor Pawlak was interested in organization of address-less machines, which were controlled by a so-called transition function. Pawlak created a new formal model of an address-less machine, which was different from a Turing machine and Rabin-Scott's finite automata. This proposal created an international interest and was called the *Pawlak machine*. At the time Professor Pawlak investigated computations realised by von Neumann machines and also alternatives, such as address-less machines.

Getting worldwide interest was another obvious success in the initial stage of Pawlak's scientific work. Let us present a few examples.

Professor Pawlak was invited to be a part of an American team, supervised by Professor Traub from University of Illinois, constructing ILLIAC IV, one of the first attempts at a massively parallel computer. Traub was familiar with Pawlak's work since he served as one of reviewers of the Pawlak habilitation thesis. Unfortunately, the government of People's Republic of Poland did not let him travel, refused to give him a passport and the plan failed.

The idea of the positional numeral system with a negative radix (-2 system) was rediscovered in the USA, ten years after Pawlak's work publication. Let us quote Pawlak's letter [24]:

> *I have recently read the above paper (S. Zohar, IEEE Trans. Computers, vol. C-19, Mar. 1970, pp. 222-226) with interest. The idea of negative radix is not new, and has been dealt with in a series of papers, some of which are noted in the references. We have in Poland over ten computers built on this principle, which have been working for over ten years. This information may be of interest to people working on the subject in the U.S.A.*

Profesor Pawlak, was one of the few Poles invited to make a plenary presentation at the *Congress of Logic, Methodology and Philosophy of Science* in Amsterdam in 1967. The lecture was entitled *On the notion of a computer* [23].

Professor Pawlak proposed a new class of parenthesis-free languages, being a generalization of Łukasiewicz's parenthesis-free notation. These results were included in the fundamental work of D. Knuth *The Art of Programming*.

In the 1970s, Professor Pawlak was interested in the formal models of the DNA. His formal model of genetic codes [21] was the world's first mathematical representation of the DNA. It was the milestone for further research [13], which helped

in incorporating the double helix structure in the formal model, leading to the rapid development of many computation models based on the DNA.

In the sixth chapter of the book Genetic Grammars ([21]), Pawlak introduced a new type of grammars, generating complex systems from the elementary ones, for instance creating proteins from aminoacids. He also presented a generalization of traditional grammars, which is still used in the formal language theory. In the book [21], Pawlak introduced a planar mosaic construction from elementary mosaics using production rules for the composition. He also presented a language for linear representation of such mosaic structures. Pawlak also proposed a two-way approach to grammars, consisting of formal grammars and constructions called picture grammars, see [45, 43, 44, 13]. Professor Solomon Marcus [13] states that Pawlak's research in formal grammars and picture grammars was a pioneering work at the time. Later, the theory of formal grammars was given a fully presention by Arto Salomaa in 1973. The first attempt at creating a general approach to picture grammars was made by Alan C. Shaw in 1967. In 1969, an extensive monograph on the topic was published by Azriel Rosenfeld. Professor Solomon Marcus describes [13] his first contact with this model (presented by Pawlak in a popular science book [21]) and the importance of this event for his own research:

> *41 years ago, Z. Pawlak has published in Polish language a book aimed perhaps as an introduction to the field of mathematical linguistics (Pawlak 1965). Short time after this event, he attended an international conference in Bucharest and I met him there. He offered me a copy of this book. As a matter of fact, he showed me the book and he said that he is sorry to have it in a language which is not available to me. But I told him that I would like to have the book and I will manage to follow it at least partly. Happy idea! Besides some usual introductory notions concerning the mathematical approach to grammars (the title in Polish: "Gramatyka i matematyka" was clearly "Grammar and mathematics"), a special chapter called my attention because it was concerned with the grammar of the genetic code. I was already introduced, at that time, to the works of Roman Jakobson and of many other authors concerning the analogy between linguistics and molecular genetics. Pawlak's approach was mainly presented in symbols, graphs and geometric pictures, while the few words in Polish were in most cases international words like codons, amino acids, nucleotides, proteins.*
>
> *It is interesting to recall the period of the sixties of the past century. After a long period in which historical linguistics used ideas and metaphors of Darwinian biology, an important change took place: instead of using biological ideas and metaphors in linguistics, linguistic ideas and metaphors related to phonemic and morphemic segmentation penetrated the study of nucleic acids, amino acids and proteins.*
>
> *To this itinerary of opposite direction in respect to the previous one, Pawlak was adding the idea of a generative perspective in the study of heredity. In this aim, he proposed a mechanism operating concomitantly in two directions. On the one hand, in the direction of formal grammars, on the other hand, in the direction of what was called later picture grammars.*
>
> *Let us recall that both formal grammars and picture grammars were at that time at their very beginning. Formal grammars theory had to wait till the year 1973 for a first satisfactory rigorous presentation (Salomaa 1973), while picture grammars had to wait until the year 1967 for a first systematic attempt (Shaw 1967) and two more years for the monograph by Rosenfeld (1969).*

[...] missing structure [a double helix structure of Watson and Crick in the approach by Pawlak] became the point of departure in Tom Head's pioneering work on DNA computing (Head 1987)[3].

In the 1970s, Pawlak and his co-workers investigated information retrieval systems (see [25, 14, 15]). In applications, information systems and query languages were expected to provide efficient up-to-date information extraction from the constantly expanding data sets. The formal model of the information system and the language for information retrieval, developed by Professor Pawlak, made it possible to create a unified approach to information retrieval and resulted in a broad analysis of the information retrieval processes' features [47].

Considering information retrieval, Professor Pawlak focused on the connection of his approach with the semantic information [26]:

It is worth to think of a more general question, namely: Is, for example, description of data sets possible only in a given way? What exactly is an information? What are its basic features? - etc. Let us observe that the notion of information, which we need to achieve the goals presented in this article, has nothing to do with the notion of information formalized in so called theory of information created by Shannon in the 1940s. In that theory, the starting points for describing information refer to sending signals in telecommunication networks. In the 1930s, the logician and philosopher Rudolf Carnap elaborated on the notion of information similar to the one we mention in this article. It might be possible to create a new theory of information based on our experience with the modern computing machines.

[...] *Almost all problems, which were raised while building and using computing machines have many different aspects - from the ones connected directly with the applications, to the ones that go beyond computing machines themselves. This is probably the reason why computer science - the science describing computing machines and their usage - is so appealing.*

Pawlak's statement about creating new theory of information proved appealing to many scientists. Nowadays, many researchers are engaged in the effort to create such theory. From the first publication on the topic of semantic information [1], the research on the range of problems in semantic information grew immensly, especially in recent years ([5, 2, 7, 8]. There is need to develop new methods of modelling complex, autonomous and adaptive dynamical systems, in which computations are realised by interactions of their components (information granules). Research on basic notions such as (interactive) computations intensified recently [9, 11].

The above-mentioned model of an information system was used in a number of approaches to data processing and mining, as fundamental representation of available data. Several years ago, the printouts of seminal Pawlak's paper published in 1981 in Information Systems [27] were distributed among the participants of the 28th ACM SIGMOD/PODS conference in Vancouver, as an important complement to Codd's vision of a relational model. This example shows a huge influence of Professor Pawlak's ideas on very diverse areas of science and industry, including in particular the mainstream research on database systems and information retrieval.

The last period of Zdzisław Pawlak's scientific work began in the 1980s and continued until he passed away in 2006. Fundamental works connected with rough set

[3] See [10].

theory are the results of that period [28, 30, 35, 36, 37]. That theory is, undoubtedly, the most important achievement of Professor Pawlak.

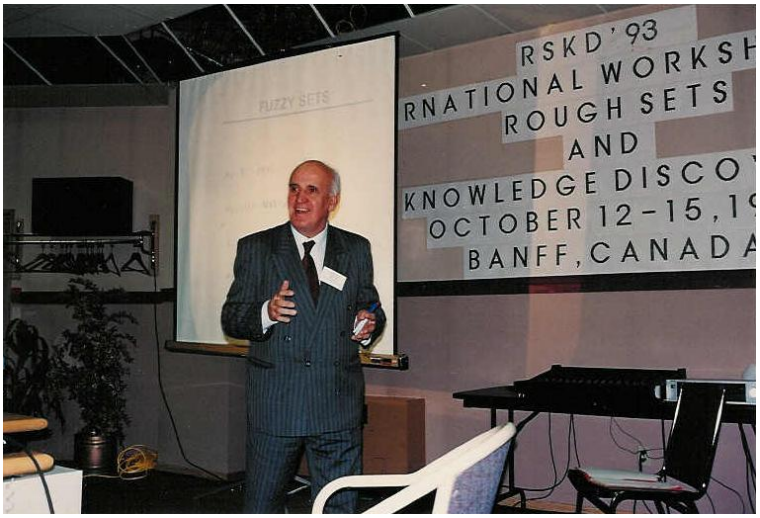


Fig. 1.5: Keynote talk of Professor Pawlak during the RSKD 1993 conference in Banff.

Roman Słowiński stated in his laudation for Zdzisław Pawlak's honorary degree in Poznań University of Technology [47]:

> *This theory helps to find answers to many basic questions in mathematics, computer science, artificial intelligence, decision theory, conflict theory, machine learning, knowledge discovery and control theory. This theory is founded on an observation that knowledge about objects from a real or abstract world is granular. Indeed, objects described by the same information are indiscernible and create elementary sets, which are knowledge granules for that world. When willing to express a concept, referring to a given set of objects, in terms of knowledge about the world the objects come from, one encounters a situation in which in general, the concept is not expressible exactly by the available granules; in other words, the union of elementary sets having non-empty intersection with our set, does not coincide with the set. This set - a concept - may, however, be expressed roughly, using sets called lower and upper approximations - lower approximation containing elementary sets (granules) which are wholly included in our set, and upper approximation containing also those sets which are partly included in our set. The difference between those approximations is called a boundary of a set, and contains ambiguous objects, for which one cannot claim with certainty, whether they do or do not belong to our set. Differentiating between definite knowledge represented by lower approximation and approximate knowledge represented by the boundary of a set has a fundamental impact on the deduction process. Rough set theory complements fuzzy set theory and soft computing, with which it now delivers the best tools for reasoning about data bearing different types of "imperfections", such as ambiguity, inaccuracy, inconsistency, incompleteness, and uncertainty.*

Since Pawlak's introduction [28] of rough sets in 1982, more than 5000 English-language publications on this topic appeared in print [55] and over 5000 Chinese-language publications [53] and books (Figure 1.7).

Fig. 1.6: Professor Zdzisław Pawlak receiving Honorary Doctorate from Poznań University of Technology (2002) - Roman Słowiński (standing on the left) delivering his laudation for Zdzisław Pawlak's honorary degree in Poznań University of Technology.

Fig. 1.7: Books on rough sets in Chinese [53].

Those publications include both specializations and extensions of rough set theory. Their goal is to solve new scientific problems, examining connections between rough set theory and other approaches to uncertainty and applying the theory in practice. A number of books devoted to rough sets theory were published worldwide.

Numerous conferences, *e.g.*, in China, India, Japan, Canada, USA and in Europe were organised. For example, in 2011, the Thirteenth International Conference on Rough Sets, Fuzzy Sets, Data Mining and Granular Computing (RSFDGrC 2011) was organised in Moscow, Russia and the 6th International Conference on Rough Sets and Knowledge Technology (RSKT 2011) was held in Banff, Canada. Many international conferences added rough sets to their lists of principal topics. Rough set

theory has an immense following in China. The First Chinese Workshop on Rough Sets and Soft Computing (CRSSC2001) was organized in May 2001, in Chongqing (see Figure 1.8). Professor Pawlak attended the workshop and gave a keynote talk. Guoyin Wang from Chongqing is reporting that this talk was very important for the development of rough sets in China. The tenth Chinese conference devoted to

Fig. 1.8: Professor Zdzisław Pawlak (the first row in the middle) with participants of the First Chinese Workshop on Rough Sets and Soft Computing (CRSSC 2001), May 2001, Chongqing.

rough set theory took place in Chongqing in 2010. In 2010 another international conference named Rough Sets in Knowledge Technology was organised in Beijing, while in Zhejiang, a successive international workshop called Rough Set Theory took place. The 2012 Joint Rough Set Symposium (JRS 2012), i.e., a joint conference of the Eighth International Conference on Rough Sets and Current Trends in Computing (RSCTC 2012) and the Seventh International Conference on Rough Sets and Knowledge Technology (RSKT 2012) will be held in Southwest Jiaotong University, Chengdu, China, August 17-20, 2012[4].

Figure 1.9 presents places in China where conferences on rough sets took place.

In his talk during the session devoted to the memory of Professor Pawlak at Rough Sets and Emerging Intelligent Systems Paradigms (RSEISP 2007) conference in 2007, Guoyin Wang, stated:

> *Professor Pawlak will eternally remain in the memory of worldwide scientific community thanks to his research achievements, which are his permanent contribution for the World Science. He had a significant impact on building friendship between Polish and Chinese scientists.*

[4] http://sist.swjtu.edu.cn/jrs2012/

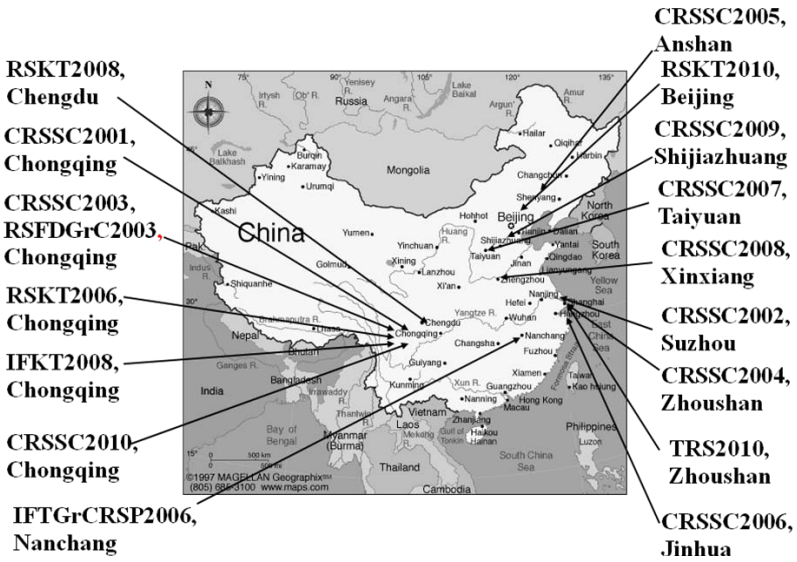


Fig. 1.9: Places in China, where conferences on rough set theory were organised [53].

For more information about the research on rough sets in China the reader is referred to [52].

Research concerning rough sets is also significantly growing in India, recently [12]. The year 2009 was called the Rough Set Year in India. There are also a lot of teams working on rough set theory and its applications at many university centres in Poland[5]. Professor Pawlak's book [30] about rough sets was, so far, quoted above 8500 times in Google Scholar. The number of valuable theoretical publications and applications basing on rough sets is constantly growing, especially when combined with other approaches to reasoning based on imperfect (often incomplete) information.

Professor Pawlak is also the author of an approach to conflict analysis [37, 29]. Andrzej Skowron is reporting comments of Professor Pawlak during a meeting in 2006:

> *I remember that during a discussion in 2006,* [*Professor Pawlak*] *was enjoying the fact that his approach to conflict analysis and conflict solving was chosen as a basis for a large project concerning negotiations between shipyards in Hong Kong.*

Out of many awards given to Professor Pawlak, he especially treasured the Hugo Steinhaus Prize awarded to him by the Polish Mathematical Society for his work on applications of mathematics and the honorary doctoral degree of the Poznań University of Technology.

[5] see `http://rsds.univ.rzeszow.pl/`

In 1996, he received the Lotfi A. Zadeh Best Paper Award. Here is a part of laudation at the award ceremony [54]:

Zdzisław Pawlak, a professor and research scientist at the Institute of Theoretical and Applied Informatics in the Polish Academy of Sciences, has won the 1996 Lotfi A. Zadeh Best Paper Award in the scientific field of soft computing for a paper entitled "On Rough Set Theory".

[...] The award will be presented during the ACM Third Joint Conference on Information Sciences to be held March 2-5, 1997, at the Sheraton Imperial Hotel and Convention Center in Research Triangle Park, N.C..

1.6 Professor Pawlak's Influence on the Development of Computer Science Community

In this section, we will present a number of testimonies of scientists discussing the influence of Pawlak on the development of Computer Science both in his native Poland and in other countries.

Professor Pawlak inspired many computer scientists and mathematicians both in Poland and throughout the world. At present his students and collaborators head research teams in many countries, including, besides of his native Poland, United States, Canada, Japan, Norway, Sweden and other places. It would be hardly possible to find a computer science institution in his native Poland without encountering faculty influenced by Pawlak. Some research centers, for instance in Warsaw, Poznań, Gdańsk, Katowice, Wrocław, and Rzeszów were formed following his initiative. His scientific achievements continue to inspire his many students that are still working there and the next generations of their students. Professor Pawlak had an unusual gift to inspire his interlocutors. As a consequence many individuals were profoundly influenced by his interests and enthusiasm towards scientific research right from the first contact with him [51].

Professor Grzegorz Rozenberg, the Director of the Leiden Center for Natural Computing has written in his letter to the participants of the International Conference on Rough Sets and Intelligent Systems Paradigms (RSEISP 2007, Warsaw, Poland, June 28-30), dedicated to the memory of Professor Pawlak:

I first met Zdzisław since 1963 - he was my mentor, then we became friends, and then family friends: Zdzisław and his wife Danuta became also good friends of my wife and of my parents.

Zdzisław was an unusually gifted scientist whose work is characterized by two main features: genuine originality and elegant simplicity. He had a gift of getting to the real essence, the root, of a research problem. Then he was able to formulate a model that was capturing this root in an elegant and transparent way. His real research interests were always on the boundary of applications and theory: he formulated theoretical models of phenomena that were highly relevant for applications. This reflected well his engineering background. His

Fig. 1.10: Professors Zdzisław Pawlak and Grzegorz Rozenberg in front of Mathematical Institute of Polish Academy of Sciences.

research was often pioneering - a good example is his model of the structure and functionality of DNA, which he formulated already in 1965.

Zdzisław was an unusually modest scientist - this modesty was totally disproportional to his scientific achievements. He was always amazed that his ideas had such a broad and profound influence. Even when he was describing to me the state-of-the-art of rough set theory, he preferred to talk about the work of others. Usually during such discussions it took me some time to figure out that many of the nice ideas really originated with him. He was a great scientist, certainly the most influential Polish computer scientist. The combination of originality, creativity, and passion for research on the one hand and such a disarming modesty on the other, made him really a role model for scientists.

[...] Zdzisław was a great scientist, but he was also a wonderful person. He had a great sense of humor and a very contiguous laugh - our sessions ended often in attacks of hiccups invoked by telling jokes and writing funny rhymes and poetry.

[...] The essence of what I want to say is that he was a great scientist and a wonderful human being of an exceptional integrity. I was really privileged to have him as a close friend. I surely miss him, I miss our phone conversations, and I often think about him. I

know that many of his friends will remember him for a long time. As a scientist he will be remembered for a very long time as there is no doubt that many of his scientific ideas have a great future.

Victor Marek (University of Kentucky, Lexington, KY) has written in his letter to the participants of the International Conference on Rough Sets and Intelligent Systems Paradigms (RSEISP 2007, Warsaw, Poland, June 28-30), dedicated to the memory of Professor Pawlak:

Fig. 1.11: Professor Zdzisław Pawlak and Victor Marek in Beskidy Mountains during the Workshop on Information Retrieval, 1974.

The problem of finding the relevant information is one of the most urgent tasks of Computer Science. Zdzisław was one of the giants who created the theory that underlies the digital revolution. Rough Sets is one of the leading paradigms for thinking about the information, as it is provided to us at the global village through the World-Wide Web.

Sankar K. Pal has written in his letter:

I first came to know about the theory of Rough Sets when I was working at the Software Technology Branch, Information Technology Division, NASA Johnson Space Center, Houston, TX, USA during 1990-92 and 1994 as a NAS-NRC Senior Research Associate. I attended some seminars on applications of rough sets in knowledge encoding in expert systems. I also had an opportunity to take part in discussions of Rough Sets by some of the university researchers who worked in our lab as summer research fellows with my advisor Dr. Robert N. Lea.

As an applied scientist working there at NASA in neuro-fuzzy computing, machine intelligence and genetic algorithms, I got motivated to work on this theory because of its major characteristics like uncertainty analysis, computation with granules and dimensionality reduction. After returning to my Indian Statistical Institute at Calcutta, I took a project from CSIR (Council of Scientific and Industrial Research, India) in 1995 and hired Dr. Mohua Banerjee who had just submitted her PhD thesis at Calcutta University. We started working

primarily on knowledge encoding problems in neural networks for knowledge based connectionist system design, and rough-fuzzy integration for obtaining a paradigm for better uncertainty analysis.

Subsequently, I got involved in an INDO-POLISH collaborative project (funded by DST, India and KBN, Poland) and visited many times Professor Andrzej Skowron and his team at the University of Warsaw. We worked together for different special issues of journals, books, and research papers mainly on granular computing, computing with words and in designing hybrid systems involving rough sets with other soft computing tools. During each of my visits, I met Professor Zdzisław Pawlak, the father of Rough Sets, a very humble and kind man, either at the office of Professor Skowron, or at his office at the Warsaw University of Technology. He attended my talks with appreciation, and we discussed various research issues. I visited his house a couple of times and cherished his paintings and other art. He also visited my Institute once in early 2000 in connection with attending a conference at Calcutta.

Fig. 1.12: In office of Andrzej Skowron (2000); from the left, Professor Zdzisław Pawlak, Marcin Szczuka, Sankar K. Pal.

Professor Pawlak is no more, but with his encouragement and blessing we could form a large group in the Machine Intelligence Unit, and establish the Center for Soft Computing Research at ISI, Kolkata, to work with this theory. Currently, the research topics include: granular computing, image processing, data mining, case based reasoning and natural computing involving rough sets either in isolation or in integration with other classical or modern soft computing tools along with their applications in bioinformatics, web mining and video surveillance. Our collaborators in the Hong Kong Poly University and the University of Naples, Italy, are also working in some of these areas. It may be mentioned here that the original definition of Soft Computing of Lotfi Zadeh had four components: Fuzzy Logic, Neuro-Computing, Genetic Algorithms, and Probabilistic Reasoning. Extension of this definition by introducing Rough Sets as Fifth Constituent is the outcome of the aforesaid research contributions of our group. This augmentation enhanced significantly the basic computational intelligence characteristics of soft computing and hence the foundation of the idea and design of high MIQ (Machine IQ) systems.

Recently, we have also formed an Indian Society for Rough Sets to promote rough set research activities in India.

Fig. 1.13: Dinner during the Rough Set Theory and Granular Computing (RSTGC 2001), Matsue, Shimane, Japan, May 20-22, 2001, (from the left) Sankar K. Pal, Professor Zdzisław Pawlak, Andrzej Skowron, Jerzy Grzymała-Busse.

While we miss the great man, we love to pay our homage to his memory through the work.

Professor Janusz Sosnowski, the head of the Institute of Computer Science at the Warsaw University of Technology wrote in his memoir [51]:

After graduation, [Professor Pawlak] worked as a junior member at the Institute of Mathematics of PAS until 1957. In this period, he took part in building the first Polish experimental "mathematical machine" (as computers were named then) GAM-1 [...]. Between 1957 and 1959, he worked at the Warsaw University of Technology, at the Chair and the Section of Telecommunications and Radio Broadcasting (KKTR), which was a very active research and construction projects centre, concerned with digital electronics (called impulse technology then) and "computing machines" [...]. In 1956, a computing machine called PARK (designed by Gerard Kudelski) was built there. Based on the experience gathered during the construction of reliable, complex electronic devices in the 1950s, the PARK group attempted to build its own "mathematical machine." Professor Pawlak played a crucial role in the project. Under his supervision and according to his design, an experimental computing machine was built at the Warsaw University of Technology. Its innovation consisted of using the positional numeral system with a negative radix (-2) and the concept of microinstruction. Based on Professor Pawlak's ideas, an Electronic Digital Machine (EMC) and, later (after Pawlak's transfer to the Mathematical Institute of PAS), a prototype (1960) and five machines of the test series of Universal Digital Machine (UMC-1) were built. The machine [UMC-1] was microprogrammed horizontally, had a drum memory and was realised in the tube technology, based on dynamic digital systems (using Havens' delay lines).

The experience gathered in the UMC-1 project resulted in creating successive generations of digital machines (UMC-10, based on transistor technology). Both, the UMC-10 prototype and the test series of UMC-10, built by the engineers of the Chair of Mathematical Machines Building turned out to be successful and reliable devices. Polish government decided to produce those machines in ELWRO factory (Wrocław, 1962 - 1964). UMC-10 was the first modern computer produced in Poland. 25 copies of UMC-10 were built and deployed.

Although the period of Professor's work [on UMC] between 1957 and 1959 may appear short, it was of crucial importance for the Warsaw University of Technology, the Faculty and

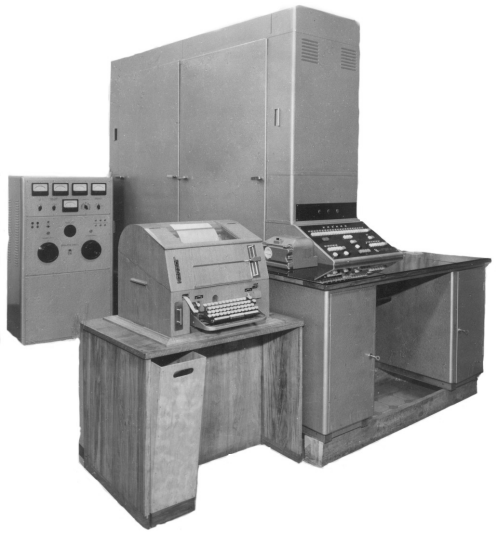


Fig. 1.14: Universal Digital Machine UMC-1.

especially for the department which was later transformed into the Institute of Computer Science (in 1975.) It was the beginning of digital and electronic computing techniques development (the contemporary name of Computer Science). Research and development work [done then] resulted in the long-term development plan of the Department. It also contributed to the fact that the Department was one of the first few centres of Computer Science. Moreover, the Department had significant achievements in educating computer scientists. The first M.Sc students specialising in mathematical machines [i.e., computer engineering] graduated in 1961.

After his transfer from the Department to the Institute of Mathematics, Pawlak's involvement with the personnel of the Department continued. He organised a seminar devoted to problems of contemporary computer science and digital electronics (researchers from the Warsaw University of Technology were also involved in the seminar). Moreover, Professor taught students specialising in building of mathematical machines and worked with many graduates from the Department and the Faculty of Electronic Engineering.

In the 1980s, the political and economical situation in Poland resulted in emigration of many important Institute researchers. Most of them made successful scientific careers in well-known foreign research centres. The result of this exodus was weakening of the scientific staff, especially among researchers with doctoral and advanced degrees. In 1988, the Institute employed only three persons having final (habilitation) degrees. To solve this crisis, we asked Professor Pawlak to come back to the Institute as its head. While being aware of the difficulties that lie ahead, Professor Pawlak accepted the invitation.

For many researchers, Professor Pawlak's return was the additional motivation to work even harder. His experience, authority and international contacts were also very helpful. Pawlak's work allowed to preserve the individuality of the Institute and to define new ways of development. At the time of Professor Pawlak return, the Institute consisted only of the Department of Computer Graphics and six laboratories, responsible for teaching and research. During the Professor's second tenure, the structure of the Institute was changed.

Starting in 1994, besides of the Department of Computer Graphics, the Institute created the Department of Software and Computer Architecture and the Department of Information Systems. This decision was crucial for further Institute's development [...].

Based on his knowledge, academic position and authority, Professor Pawlak introduced a new, modern subject, based on a branch of Artificial Intelligence, to the Institute. That was the area of reasoning from uncertain or inaccurate data.

After his retirement in 1996, Professor Pawlak continued to be involved in Institute's matters to the end of his days. He visited the head's office on a regular basis and worked with the researchers of the Institute of Computer Science.

[...] Professor Pawlak had a very important role in integrating the scientific communities of mathematicians and technical scientists. He significantly broadened the research interests of many workers of the Institute. In 1998, the Faculty of Electronics and Information Technology, and the Institute of Computer Science helped to organise an international conference in Warsaw, devoted to rough sets (the 1st International Conference on Rough Sets and Current Trends in Computing (RSCTC)). It was an important scientific event, bringing together experts from many branches of science.

[...] Professor Pawlak was concerned with the pace of computer science development at our Technical University and in the country. He compared it with situation at the similar faculties at the leading foreign universities. He tried to make aware the scientific community of Warsaw University of Technology of the situation.

Professor Piotr Dembiński, director of the Institute of Computer Science of PAS in Warsaw over many years, writes in his memoirs [51]:

[...] As everybody old enough remembers, the beginning of the 1970s and its subsequent years were not the best time for the development of our native computer technology. In that situation, Professor Pawlak decided that it is necessary to focus on the areas in which we were able to succeed worldwide rather than in our country alone. Theoretical (mathematical) foundations of computer science appeared to be such a branch. We – researchers of the Computer Centre – and other people gathered around him were prepared and educated to research this area. Furthermore, the mathematical tools and language were natural to this kind of scientific work.

The choice appeared right. Mathematical Foundations of Computer Science began to shape the scientific profile of the Computer Centre, which was renamed the Institute of Computer Science of PAS in 1976. It is possible to say that Professor Pawlak was an actual creator of the Institute and the main leader of the research conducted there.

To present the results of the Institute's work worldwide, Professor Pawlak motivated us to organise a conference series concerned with the mathematical foundations of computer science in 1972 (Mathematical Foundations of Computer Science - MFCS), which took place annually in Poland and Czechoslovakia (alternating the country each year) and, from 1989, in Poland, Czech Republic and Slovakia. MFCS was the only and unique scientific event of that time, where scientists from both sides of the Iron Curtain gathered. The Conference has not lost its prestige so far.

Professor Pawlak and Professor Rasiowa were also the initiators of establishing a scientific journal called Fundamenta Informaticae, which quickly became renowned in the worldwide scientific community and, as a result, got a high rated position on the ISI Master Journal List.

Alicja Wakulicz-Deja, the president of the Institute of Computer Science at the University of Silesia, recalls Professor [51]:

Professor Zdzisław Pawlak was one of the initiators of creation of the Institute of Computer Science at the University of Silesia and the director of the Institute between 1979 and 1986. He was our co-worker and mentor of the Institute's staff. During his work at the Institute,

he conducted seminars and spent much time on face-to-face scientific discussions with the researchers of the institute.

He always looked for new scientific problems - his ideas inspired his young co-workers. We owe him the first significant publications of the Institute of Computer Science and presentations of our research at many national and international conferences.

Professor Pawlak was a very demanding as a scientist and, while often using quick wit and jokes, he created an atmosphere of great respect for his knowledge and intelligence.

Professor Pawlak left the Institute in 1986 because of his personal and health problems. However, he was always interested in research and work of our Institute. He repeatedly asked me to visit him in Warsaw and report on the progress of the Institute. He was pleased with our achievements and advised how to solve our problems. In particular, he said that "if anybody is able to replace us, we should start researching something new." He also thought that primitive and unfriendly people should be avoided because "if you step in the mud, it will leave a stain on your shoes".

[...] I met Professor Zdzisław Pawlak during my last year of studies at the Faculty of Electronic Engineering (specialization - Digital Machines) in Technical University of Warsaw, when he proposed topics for master theses. I chose the topic called "The Graph Grammars and Digital Mathematical Machines". At that time, Professor Pawlak was a docent (Associate Professor) at the Institute of Mathematical Machines, where he took part in building an arithmetic logic unit for the ZAM 41 machine, which was implemented with Pawlak's system (negative 2 base radix).

Thus my collaboration with Professor Pawlak began from the period of his work, which may be called the phase of "Pawlak Machine" then continuing through the phase of the machine specified with the instruction set (my doctoral thesis) to the information systems (postdoctoral degree) and decision support systems (application of rough set theory).

This collaboration taught me to perceive computer science as a fully mature branch of science, the ultimate goal of Professor Pawlak's. He also thought us that one must not develop a theory which has no applications and frequently told us to search for applications of theories we developed.

Professor Jerzy Dembczyński, Rector of the Poznań University of Technology, wrote in the laudation opening the ceremony of awarding Professor Pawlak a honorary doctorate degree [3]:

Fig. 1.15: The ceremony of awarding Professor Zdzisław Pawlak honorary doctorate degree: Jerzy Dembczyński, Rector of the Poznań University is giving flowers to Professor Pawlak.

[...] the time has come to thank one of the pioneers of Polish and international computer science, the hero of this ceremony, much-esteemed laureate, Professor Zdzisław I. Pawlak. His contributions to computer science are respected throughout the world. He was instrumental in creating the first Polish digital machine. He is also the first Pole whose scientific work in computer science was published in a prestigious western scientific journal. Professor Pawlak presented the first mathematical model of the DNA, while the laureate's adress-less machine model earned him great respect throughout scientific community. The abundance of his scientific achievements is still growing; we owe him fundamental work on theory of rough sets and granular computing.

[...] The collaboration of Professor Zdzisław I. Pawlak with the Institute of Automation and, later, the Institute of Computer Science at the Poznań University of Technology started in the 1970s and still continues.

Let us quote Roman Słowiński's words [47]:

Looking at him from our, Poznań, perspective, we are grateful to Professor Pawlak for introducing us to rough set theory at its very beginning and for letting us to perform its first practical verifications - it was the application of rough set theory to decision support in medicine. In 1992, Poznań was honoured to organise the first seminar (see Figure 1.16) dedicated to this subject. This seminar began a series of international conferences in Canada, USA, Japan, and Poland. An international scientific association was also founded – International Rough Set Society.

Fig. 1.16: Participants of the first international seminar on rough sets in Kiekrz near Poznań, 1992; (lying from the left) Professor Zdzisław Pawlak and Barbara Wołyńska, (crouching from the left) Zdzisław Piasta, Cecylia Rauszer, Jerzy W. Grzymała-Busse, Jerzy Stefanowski, Andrzej Skowron, Wojciech Ziarko, Piotr Sapiecha, Leszek Płonka, (standing from the left) Ramin Yasdi, Maciej Kandulski, Mohua Banerjee, Jacek Marciniec, Jerzy Krysiński, Janusz Szymaś, T.Y. Lin, Maciej Modrzejewski, El Sanossy Abobaker Sharif, Lech Polkowski, Ewa Orłowska, Jarosław Stepaniuk, Roman Słowiński, Krzysztof Słowiński.

[...] Ladies and gentlemen, we have an honour to reward an eminent scientist, with great achievements for Polish and international computer science development, tireless seeker of answers to difficult and fundamental questions in science, man of impeccable reputation, and Poznań University of Technology's friend of a long standing.

While being an acknowledged authority in scientific research, Professor Pawlak is a humble and kind-hearted man. In contacts with young researchers, he transmits his enthusiasm and friendly encouragement. One can also enjoy talking with him on other topics than computer science - he is a connoisseur of photography, and, moreover, since a couple of years he is painting pictures, which show his extraordinary sensitivity to a subtle play of lights in a landscape[6].

Fig. 1.17: "Winter" painted by Zdzisław Pawlak.

Professor Mihir Kr. Chakraborty in his letter "Remembering Professor Pawlak" writes:

I remember my first meeting with professor Z. Pawlak at his drawing room in Warsaw on a chilly winter. We had a long discussion full of excitement on uncertainty, vagueness and his own theory of rough sets. Professor offered me a fantastic dinner. And in the end, I expressed my willingness to work on his theory provided I got a young mind to collaborate. Fortunately, within a short period Mohua (Banerjee), a very talented fresh graduate of the department of Pure mathematics, University of Calcutta approached me to supervise her Ph.D. work. I asked her to read some papers on rough set theory and to see if she liked them. Fortunately again, Mohua took up the subject with great enthusiasm and completed her dissertation. She was the first researcher in this field in India. Since that time we have been working together. Jointly we wrote a paper with the title "Pawlak's landscaping with rough sets" – reflecting that Pawlak was a painter who used to paint with rough brush-strokes. We are trying to popularize the theory in India and feel that some amount of success has been achieved. Mohua also was very close to Professor Pawlak. When we received the news of his demise we had been greatly shocked and sent a few lines to Professor Andrzej Skowron as a tribute to Professor Pawlak and as an expression of our deepest respect to his memory,

[6] See Figure 1.17.

I would like to present those lines once again.

Good bye Professor Pawlak

What had been inevitable has happened.
We had been silently apprehending this last moment.

We cherish all the nice memories of every bit of our togetherness
the evenings, nights, working mornings, cosy corners, the lody
riversides, long drives, smiles, quarrels, Warsaw, Paris, Banff
the Niagra, Calcutta

We wished to meet you in pains. We could not

Now we shall paint you on our heart as you painted the nature on canvas
We could roughly walk along the beautiful path you have created as a mathematical-artist
We hope to go on further

Our regards, tears and best wishes for your steps into the unknown

Good bye Papa Pawlak.

Fig. 1.18: Visit of Mohua Banerjee in Warsaw 1992, (from the left) Professor Zdzisław Pawlak, Mohua Banerjee, and Janusz Kacprzyk.

Fig. 1.19: During International Conference on Fuzzy Systems (AFSS 2002), Calcutta, India, February 3-6, 2002; Professor Zdzisław Pawlak with parents of Mohua Benerjee and Mihir Kr. Chakraborty (on the left).

Shusaku Tsumoto in his letter “Encounter with Professor Pawlak” writes:

Fig. 1.20: RSFDGrC 1999, Yamaguchi, Japan; (from the right) Professor Pawlak, Shusaku Tsumoto with wife and Ning Zhong.

My Research Concern from 1986-1988.

I was involved in development of RHINOS, and interested in characterization of medical reasoning when I interviewed the domain experts for knowledge acquisition. On the other hand, development of electronic patient records was ongoing, and I forsaw that healthcare records will be used as a dataset and automated acquisition of knowledge base would be an important topic in medical informatics.

Residents from 1989-1991.

After I was graduated from Osaka University, School of Medicine, I worked for Chiba University Hospital as a resident of Neurology from 1989 to Sep 1990, and moved to Emergency Department of Matsudo Municipal Hospital for one year. From Oct 1991, I worked as a research associate of division of medical informatics, and was involved in development of hospital information systems.

Encounter with Pawlak’s book: 1991.

When I worked for emergency department of Matsudo municipal hospital, every week I visited a large bookstore called Yaesu Book Center in front of Tokyo Station. I found Pawlak’s book on one Saturday afternoon. I looked it through and found it interesting. However, I was looking for other book on AI and I hesitated buying it. I repeated taking it in hand and putting back into the bookshelf. Since I did not find any interesting book that day, I bought his book. At that time, I did not notice that reasoning of our expert system corresponds to rough sets and I put Pawlak’s book on the desk, not the bookshelf.

Encounter with Rough Sets: 1992 to 1993.

I read his book during Xmas in 1992 in order to give some subject to the seminar in Tokyo Medical and Dental University. In 1993 when I moved to this university as an associate professor, I had found that the core ideas have correspondence to the reasoning of our expert system (RHINOS). That is, exclusive rules and inclusive rules are corresponding to the rules obtained from upper and lower approximation of a given concept. I started my study on rough sets since then.

Workshop in Banff: 1993.

I found a name "RSKD2003" (Rough Sets and Knowledge Discovery) in IEEE Expert and I sent an email to Prof. Ziarko. Although the dealine had passed, he encouraged me to submit my papers. I presented my idea in RSKD2003, which was a very nice workshop and I met Pawlak's family: many important person Profs. Pawlak, Skowron, Słowiński, Ziarko, Cercone, Lin, Yao and Hu. This was the starting point of my research on rough sets and data mining.

Meeting with Professor Pawlak.

I attended Pawlak's plenary talk on conflict analysis, which can be viewed as formal analysis on asymmetric relation [31, 34]. This was the most impressive talk in this workshop: Professor Pawlak was very strong, energetic and research-minded. This is the moment when I had decided to work for rough sets.

Dr Urszula Stańczyk, in her memoirs about Professor Adam Mrózek from the Institute of Theoretical and Applied Informatics of PAS and the Silesian University of Technology in Gliwice, writes [49]:

In the beginning of the 1980s, Professor Mrózek contacted Professor Zdzisław Pawlak, the creator of rough set theory. Elements of this theory turned out very quickly to be effective in analysis and minimization of arrays describing behaviour of operator-experts. Meeting Professor Pawlak had a crucial impact on A. Mrózek's future research. Applying rough set theory, in the last years of Professor Mrózek's life, resulted in introducing the idea of so called rough controller and broadening the fields of theory's application to economical processes and medical diagnosis.

The last example of Professor Pawlak's inspiration outlined in this section, reported by Dominik Ślęzak, relates to development of a commercial database system available worldwide since 2005 (with its open source version launched in 2008[7]). The idea behind its efficiency lays in data granulation and adoption of principles of rough set approximations to dynamically identify only those granules which are truly required to resolve the incoming SQL statements. Let us refer to two fragments describing this technology, taken from the blog of one of the most influential database analysts[8]. The first fragment was published in 2008:

[...] The "rough set" part of Infobright's story is a lot of mumbo-jumbo [...]

The second fragment comes in 2011:

[...] Rough Query estimates query results [...] To me, Rough Query is the most impressive part of the Infobright 4.0 announcement. [...]

[7] www.infobright.org

[8] www.dbms2.com

In our opinion, the two above excerpts illustrate that it always takes time for industry to accept new ideas. Moreover, only those ideas which are simple and powerful enough can survive. It cannot be a coincidence that so many ideas of Zdzisław Pawlak are nowadays present in so many areas of research and applications.

We close this section with some pictures from the rough set meetings.

Fig. 1.21: San Jose 1994: International Workshop on Rough Sets and Soft Computing (RSSC 1994), San Jose, CA, USA, November 10-12, 1994; from the left: Krzysztof Słowiński, Lech Polkowski, Andrzej Skowron, Robert Golan, Marzena Kryszkiewicz, Jerzy Grzymała-Busse, Shusaku Tsumoto, Zdzisław Piasta, Krzysztof Krawiec, Wojciech Ziarko, Roman Słowiński, Professor Zdzisaw Pawlak.

Fig. 1.22: Joint Conference on Information Science, Wrightsville Beach, 1995; from the right: Professor Zdzisław Pawlak, Marzena Kryszkiewicz, Hung Son Nguyen, Jerzy Grzymała-Busse, Wojciech Ziarko, Anna Ziarko, Zbigniew Raś

Fig. 1.23: Tokyo 1996: Fourth International Workshop on Rough Sets, Fuzzy Sets and Machine Discovery (RSFD 1996), Tokyo, Nov. 6-8, 1996; from the left: Jerzy Stefanowski, Shusaku Tsumoto, Lotfi Zadeh, Wojciech Ziarko, Professor Zdzisław Pawlak, Roman Słowiński.

Fig. 1.24: Visit in Kyoto after RSFDGrC 1999 conference in Yamaguchi, Japan; from the right (in front): wife of Grzymała-Busse, Sheela Ramanna, from the right (behind) James Peters, Marcin Szczuka, Jan Żytkow, Andrzej Skowron, Professor Zdzisław Pawlak and (behind) Yoshitsugu Kakemoto.

1.7 Zdzisław Pawlak and Artificial Intelligence

In this section, we discuss the idea of Artificial Intelligence as developed in the work of Professor Pawlak and his closest collaborators, including Professor Helena Rasiowa.

Here is a recollection of Andrzej Skowron.

Professor Pawlak and Professor Helena Rasiowa conducted a research seminar on automated theorem proving, at the Faculty of Mathematics and Mechanics of the University of Warsaw.

Fig. 1.25: Professor Helena Rasiowa and Professor Zdzisław Pawlak.

I remember this as if it was today. I remember a big auditorium filled with participants of the seminar. In that period, Professor Pawlak conducted an intensive research related to mathematical models of computers and computations realised by them. He lectured and conducted seminars for students of mathematics and computer science. The cooperation with Professor Helena Rasiowa and her research team began in the early 1960s and lasted

for many years. The results of this collaboration are still important. One may safely say that a new research school came into existence [11]. This cooperation had a lot of influence on shaping many people's scientific research and on the evolution of main notions of logic researched by Professor Rasiowa's group [11]: from the classical logic to non-classical logic and its inference processes, the main characteristics of current Artificial Intelligence investigations.

We found the first trace of Professor Pawlak's interest in Artificial Intelligence in an article [18] from 1956, in which he discusses the relationship between mathematical machines ("apparatuses") and cybernetics:

Robots, humans, homunculuses, mechanical animals, chess machines, and other similar wonders - until recently the domain of mad scientists, inventors, alchemists, common deceivers and, at the best case, science fiction writers - are now getting popular among absolutely normal, lucid people and even renowned and respected scholars. This change was triggered during the last war by a famous American mathematician Norbert Wiener. [...] He came into conclusion that modern mathematical apparatuses are almost ideal models of many phenomena happening in the nervous system and, partly, models of phenomena happening in a society. This created basis for renaissance of mechanicism in biology and sociology. This new mechanicism is called cybernetics.

Professor Pawlak warned in [18] that

[...] it is worth to be aware of the fact that an apparatus is not an organism and the analogies between them are secondary, while differences are fundamental.

and

[...] Capabilities of existing, even the strongest apparatuses do not exceed a range of "primitive work".

[...] Looking at the "electronic brain" [...] a faint sign of intelligence and thinking should be expected - features, which no mathematical apparatus has. [at present]

Similar opinions appear again in [19] in 1963:

The role of mathematical machines in mathematics has its strictly determined limits. It seems even less probable for them to play a significant role in other sciences, especially in the humanities. The hopes of cyberneticians for creating a homunculus seem unfounded. [...] there is a similarity between machines and living organisms but it has a surface character, while the differences are fundamental. The history of machines differs from the one of bio-organisms and I do not believe they are ever going to converge.

Is cybernetics a worthless game, then? Probably not. Cybernetics extended the range of engineers' interests to the humanities, while humanists' to engineering. To sum up, cybernetics may indirectly influence the way of the technical development, as well as other sciences progress.

In a later period, up to the beginning of the 1980s, Professor Pawlak did not publish works which were directly concerned with Artificial Intelligence. However, his works, mentioned above, referring, *e.g.*, to computation models realised by addressless machines [20, 22] or inspired by biological processes [21, 13] clearly shows that he was intrigued with various computation models and searching for alternative models to those realised in von Neumann's machines, models that had the potential to cause the next technological revolution. He expressed that idea in the lecture during the award ceremony at Poznań University of Technology [33]:

We are still unable to provide the parallel algorithm theory, in spite of the huge development of parallel and concurrent systems. New computation models are being developed for, e.g.*, DNA computing and quantum computing. In this context, it is instructive to think about Noble Prizes awarded in 1998 for the work related to computers:*

- *in Physics, for the results in researching quantum phenomena as a basis for computers (Robert Laughlin, Horest Stoermer, Daniel Tsui);*
- *in Chemistry, for the development of computing methods (Walter Kohn, John Pople).*

[...] meteorology, aerodynamics, genetics or cryptography demand significantly bigger computational power. I refer not only to increasing the speed of computing but, generally, to finding a new computing paradigm, because modern computers, based on von Neumann's idea, are reaching the limits of their capabilities. This task may be very difficult to realise without new concepts of concurrent and parallel computing on a large scale.

As we see, Professor Pawlak was still intrigued by new computation models. He searched for them, while working on computation models of von Neumann's machines, computation models inspired by biological processes or computation models for automated theorem proving. However, he found all of these models insufficient to solve the real difficulties in creating Artificial Intelligence [33]:

In spite of the computers' enormous successes in science, their role is limited. In the most important scientific tasks: creating and verifying hypotheses, computers did not play any important role so far. The example of Fermat's Last Theorem is symptomatic here. This is because we do not understand the essence of a scientific discovery and the role of intuition, associations etc. Picasso commented on this in a very dramatic manner. (Compare with the motto of [33]: "Computers are useless. They do not pose questions.")

We quote another excerpt of Professor Pawlak's lecture at the Poznań University of Technology [33], referring to issues connected to computation models and Artificial Intelligence:

Proving a hypothesis in inductive logic is done, unlike in deductive logic, not by formal reasoning, but on the basis of experiment. Physics illustrates it best. Researching inductive logic has a long history. An eminent English philosopher John Stuart Mill (1806-1873) is considered its founder. The creation of computers and their innovative applications influenced the rapid growth of interest in inductive reasoning. At present this area develops really dynamically thanks to computer science techniques. Machine learning, knowledge discovery, reasoning from data, expert systems, and other techniques are the examples on new directions in inductive reasoning.

[...] A research in the theory of induction owes computer science new impulses too. However, we are far from the situation similar to the one in deductive logic. There are no emerging outlines of theory of induction, having the same status as the theory of deduction.

[...] Finally, the most interesting technology, from the computer scientist's point of view, is the common-sense reasoning. This is the reasoning which people use in everyday life, politics and many humanities. The starting point of that kind of reasoning is knowledge possessed by a certain group of people ("common knowledge") about a subject, and intuitive methods of reasoning from that knowledge. Examples of that type of reasoning are commonly seen in press, radio and television. They are concerned with politics, economy or arts. Parliamentary debates are a classic example of common-sense reasoning. Governing parties give arguments for accepting the budget, saying that it is excellent, while opposition parties counter their arguments. Who is right, then? Neither deductive logic (reasoning) nor inductive logic (experiment) may solve the problem. That is why voting is the only chance to settle the argument. The result of voting does not make a thesis valid or not. Of course

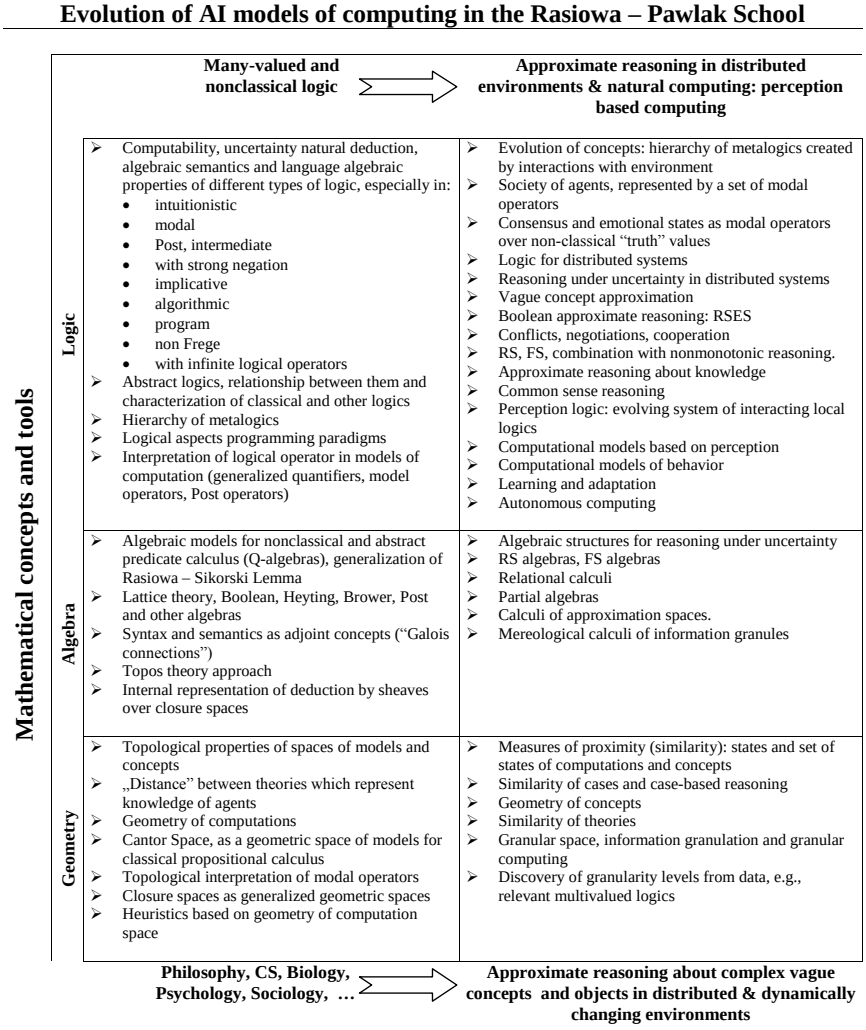


Fig. 1.26: Models' evolution in the Rasiowa - Pawlak research school.

this method is unacceptable in mathematics or physics. Nobody will judge the correctness of Fermat's theorem or Newton's equations by voting. The theory of this type of reasoning still awaits significant development. Moreover, its structure is not sufficiently understood. However, there were some investigations of the subject. The common-sense reasoning is really significant because of its range and importance in some fields. Computer science may play an important role here, on the condition that one would understand the essence of this reasoning thoroughly. This can be achieved by making an appropriate theoretical studies.

Undoubtedly, the discovery of rough set theory gave a strong impulse to work on understanding the essence of reasoning mentioned above. Some investigations point to the connections between rough sets and existing formalisms of common-sense reasoning including default logic [4]. Research on relationships between rough sets and paraconsistent logics still flourishes [50]. In our opinion, further understanding of common-sense reasoning's essence may be achieved with better understanding of the fundamentals and capabilities of interactive granular computing. Rough sets play a significant role in defining this form of computing. The programme of this research is presented in [11].

We close this section with a statement of Professor Toshinori Munakata (Cleveland State University) [16]:

It is an honor to contribute my short article to this special issue commemorating the life and work of Professor Zdzisław Pawlak. In this article I would like to discuss my encounters with the field of artificial intelligence (AI) in general, and how I see rough set theory and Professor Zdzisław Pawlak in this context. I have been fortunate to know some of the greatest scholars in the AI field. There are many of them, but if I had to choose the three I admire most, they are: Professors Pawlak, Lotfi Zadeh and Herbert A. Simon. There are common characteristics among all of them. Although they are the most prominent of scholars, all are frank and easy and pleasant to talk with. All are professionally active at ages where ordinary people would have long since retired.

[...] For knowledge discovery techniques such as rough sets, there may be a limit when we deal only with decision tables. Perhaps we should also look at other formats of data as well as other types of data, for example, non-text, comprehensive types of information, such as symbolic, visual, audio, etc. Also, the use of huge background knowledge, in a manner similar to human thought, would be necessary and effective. Human-computer interactions would also enhance the discovery processes. Other totally different domains are non-silicon based new computing paradigms. I am currently working on my fourth Special Section for the Communications of the ACM as a guest editor on this subject [...]. These approaches may lead to a new dimension of information processing in a wide range of application domains including rough sets. As with other scientific developments in history, such as alchemy and the first airplane, a breakthrough may come in a totally unexpected form.

1.8 People and Nature

Professor Pawlak was a lively and witty person. He felt comfortable among other people (especially friends, see pictures included in this paper) and he adored nature. After relaxing surrounded by nature he would regenerate fast and get back to his intensive scientific work, for which he dedicated his life.

Jerzy Grzymała-Busse writes about visits of Professor Pawlak at the University of Kansas:

Between 1984 and 1994 Professor Zdzisław Pawlak visited the University of Kansas several times. The main reason for his visits was to present his research on rough sets, mostly through invited scientific talks. During these visits, Professor Pawlak lived in the home of Jerzy Grzymałla-Busse and became - practically - a family member. They went on many walks together, as well as trips to local attractions. He participated in various family activities, including the kids' track and field competitions, and trips to a shooting range to shoot M14 and M16 military rifles.

Fig. 1.27: Visit in Kansas, Professor Zdzisław Pawlak enjoying activities on slide with children of Jerzy Grzymała-Busse; from the top: son Jan, Professor Pawlak, daughter Anna, and son Witold.

Fig. 1.28: Visit in Kansas, Professor Zdzisław Pawlak in a military uniform with Jerzy Grzymała-Busse family; from the left: son Jan, wife Dobroslawa, daughter Anna, and Jerzy Grzymała-Busse.

He loved to go with the younger members of the Grzymała-Busse family to playgrounds, participating and enjoying the activities (Photograph 1.27). One of his hobbies was hunting for interesting and rare things at local garage sales. Photograph 1.28 shows Professor Pawlak proudly sporting a military uniform.

James Peters (University of Manitoba) writes:

In a short time that I knew him, he was like a father for me. ... He changed my [life] in many ways.

Professor Pawlak was not only a pioneer in mathematics and computer science, he was also a gifted painter of scenes from nature. His interest in enshrining moments in the changing seasons in the Polish countryside in paintings began in the 1950. One of his earliest

paintings (a waterscape) was signed by him in 1954. His interest in painting continued through his life.

His paintings capture various moments in the four seasons in the Polish countryside. In a vivid way, his paintings offer his perception of the symmetries and singular beauty of the woods, gently rolling terrain, lakes and shorelines that he visited in Poland. A persistent theme in Professor Pawlak's paintings are watershadows of trees and waterway reeds. These watershadows manifest Professor Pawlak's interest in the portrayal of actual objects such as trees in an approximate but beautiful way. In some sense, Professor Pawlak painted border regions of elongated watershadows that is reminiscent of his basic idea of set approximations in rough set theory. See, e.g.*, Figure 1.29, for a sample painting by Professor Pawlak from the late 1990s.*

Fig. 1.29: A sample painting by Professor Pawlak from the late 1990s.

Professors Andrzej Czyżewski and Bożena Kostek describe a story behind the Alaskan scenery:

In 1998, May 4th-9th Andrzej Czyżewski and Bożena Kostek had an occasion of participating in the 7th IEEE International Conference on Fuzzy Systems organized in Anchorage, Alaska, USA. A special session devoted to rough sets was organized at this conference, thus it attracted some members of the rough set community, including the founder of rough set theory - Professor Zdzisław Pawlak, who presented a keynote speech at that conference.

On May 10th, the day following the conference, they organized a car tour around Anchorage in order to catch a glimpse of the incredible Alaskan scenery and landscapes. Professor Pawlak and Lech Polkowski accepted their invitation and they all had a very nice time together, because the previously capricious weather changed on that day allowing us to watch the sun beaming to snowy mountains (see Photographs 1.40-1.41).

Professor Pawlak seemed impressed with the picturesque view of the snowy peaks and wild landscapes. As it was revealed later, those impressions lasted for long in his sensitive painter's soul. When Andrzej Czyżewski went to Professor Pawlak's Warsaw home many years later, he asked for visiting the small painting gallery located in a room of the home. Among many Professor Pawlak's paintings the Alaskan landscapes shone brightly, catching an attention of the viewer. The last visit of Andrzej Czyżewski in Professor Pawlak's home located at Zuga street in Warsaw was tinted with unspoken awareness of the serious illness of the host. Despite that, as usually, Professor Pawlak seemed to take it easily and even joked. He said: "take this picture now, because after painter's death the price may rise

seriously". With those words he took the painting off from the wall and handed it to Andrzej Czyżewski, who got a little bit confused with this act. "I cannot accept such a gift" - he said. Professor Pawlak responded: "it is not for free, you have to pay for it, but not for me. Pay one million dollars or less (he smiled jokingly) to some people who may really need money". Soon they parted, exchanging their last view when Andrzej Czyżewski loaded the painting into his car. He decided right after to respect the donator's will and supplied a hospice in Poland in return to Professor Pawlak's gift.

Today the painting (see the photocopy of it in Photograph 1.30) hangs on the wall inside Andrzej Czyżewski's and Bożena Kostek's home reminding them Professor Zdzisław Pawlak who was world-renowned scientist, with so many talents and at the same time so unpretentious, approaching much younger colleagues in a very natural, friendly and warm manners.

Fig. 1.30: A sample painting by Professor Pawlak: Alaska, 1999.

Professor Dembiński (Institute of Computer Science of PAS) writes in his memoirs [51]:

Professor Pawlak was a modest person, and often began his presentations with the words "I am not sure, if it is significant, but [...]

[...] Professor Pawlak had wide interests and had many talents, for instance he sang very well and he knew probably all operetta arias by heart. At the end of his life he was often painting. His paintings could compete with the work of professional artists. He often jokingly collected diplomas attesting to his various achievements, not only scientific ones. So, for instance he got from my wife - a professional dancer - certificate about his high dance skills. Similarly, in pilot school ("Szkoła Orląt") in Dęblin, he asked commanding officer - General Olszewski - for a diploma of a jet plane test pilot, after his flight with General.

[...] Professor Pawlak – outstanding scientist and mentor – a person with many talents.

Professor Janusz Sosnowski of the Warsaw University of Technology describes Professor Pawlak with these words [51]:

He was a very cheerful person with a sense of humour and abundant interests beyond the scientific ones. Taking over the Institute's administration after Professor Pawlak's retirement (1996), I was facing many difficult problems both inside of the Institute and in our relations with the administration. At that time, helpful discussions with the Professor assisted

me in surviving difficult moments and finding appropriate solutions. Professor Pawlak was also able to appreciate achievements of others and willing to help them in their work, which are unusual features in scientific environment.

Mr Jerzy Fiett, Professor's friend, writes in his testimonial presented during one of the sessions devoted to the memory of Professor Pawlak:

How many years have passed, when young (then) people: Zdzisław Pawlak - "Kłaczek", Mieczysław Zielczyński - "Miećka", Andrzej Janikowski and Jerzy Fiett, members of exclusive Old Bachelors' Club from the 1950s, made up a group that could do the impossible and put even the wildest ideas into operation? Andrew is not with us anymore. He rests eternally in Stara Miłosna. Zdzisław, after achieving everything in his scientific career, still works in his profession, in spite of serious health problems. Moreover, he paints really great, writes, and still has new plans.

Professor Pawlak often recalled excursions to Bieszczady Mountains, which took place after the WW II. Here is a fragment of Mr Fiett's memories of these trips:

A camp on Szeroki Wierch, frost cracking of trees, a trip to Halicz via Tarnica - Krzemień (that damn frost traverse!), return at sunset, beautiful downhill ride from Tarnica on the snowy drifts. Another freezing night, drying and freezing boots for the night, drying gloves and socks with "on belly" method - beautiful morning, hoarfrosty replicas of socks and gloves on our sleeping bags! Stonefrost, icy boots. Next, after a proper breakfast, to the place, where Berehy Górne used to be. Incredibly hard struggling to go with resistant toboggan, constantly playing tricks, through the snowy, sloping bushes, filled with surprises in the form of snowdrifts, rifts and other obstacles. Next, walking on a bit friendlier terrain for some time, to the tiny Lemken cemetery and a few chimneys sticking out from the snow. That was all that was left from Berehy Górne village. Near the site of a fire, on a broad opening covered with deep snow, frozen to the bones, we put up our tents and prepare a place to sleep. We collect timber to make a bonfire and surround our tents with previously cut wood. That is how we made our new campsite. Sleeping is not going to be comfortable, like during the previous nights. We cover the floors of our tents with cloth, on which we lay a self-made mattress, consisting of four rubber tubes and sackcloth binding. We lay our blankets and sleeping bags on the improvised floor and use backpacks as pillows.

Andrzej Skowron recollects:

Masurian lakes were Professor's most favourite areas, and we used to go there together during the last years of his life. I had an impression that not only does he know every lake there, but also every path, stone and tree.

Here is another fragment of Mr Fiett's memories of trips to the lakes:

The day after a relatively peaceful canoeing trip's segment, the most beautiful but the wildest and the most difficult section (called "a little hell") begins. We row through the great tunnel, shaded with thick branches of trees growing on both sides of the river, going with the strong current. We row through the winding riverbed swarming with rocks, sometimes pretty sharp, and with fallen trees, struggling to protect our boats from breaking - as we can, using paddles or hands. However, it is really beautiful here! Zdzisiek [Professor Pawlak's nickname]*, intrepid photographer, takes photos of his companions (Andrzej and Miećka). These photos were a precious memory of our trip down Wel river and were awarded first prize in the [London] Times' photographic contest (see Figure 1.32).*

Fig. 1.31: Picture made by Professor Pawlak in early 1950s in Bieszczady.

1.9 Conclusions

Here we conclude our celebration of Professor Pawlak's life with few testimonies from students and collaborators. Other testimonies can be found in [6, 38, 39, 40, 48, 41]. A volume of Fundamenta Informaticae [46] includes articles dedicated to Professor Pawlak.

During one of the reminiscence sessions devoted to Professor Pawlak, Roman Słowiński stated:

> *The road which led Professor Pawlak to his crucial discoveries was long but ended successfully. Over fifty years, Professor Pawlak researched many areas of computer science. Without hesitation one can say that his personal path is one of the most important ones from the fifty-year-old history of research in Polish and worldwide computer science."*

During the same session, James Peters and Andrzej Skowron recalled the Professor:

> *Zdzisław Pawlak gave an abundance of his time and energy to help others. His personality and insight had, undoubtedly, influenced many scientists around the World. He had a unique gift to inspire his students, co-workers and many scientists beyond his close circle of collaborators to do research. Professor's associates recognized his extraordinary character. Many called him "Our Papa Pawlak".*
>
> *[...] Professor Zdzisław Pawlak was with us only for a while. However, when we consider his talents and great achievements, we know how much he influenced us and our successes with his research work in many areas like approximate reasoning, intelligent information*

Fig. 1.32: Polish jungle: Times' photographical contest award (1950s).

systems, computation models and foundations of computer science, and of artificial intelligence - especially including rough set theory, molecular computing, pattern recognition, philosophy, art, and poetry. He also influenced us with his uncommonly rich personality.

Alicja Wakulicz-Deja farewelled Professor saying [51]:

Our meetings lasted to his last days.

[...] He seemed indestructible. However, his struggle with severe illness was very hard. When I was afraid that he was getting tired during our meetings and ask him if anything hurts him, he replied: "Let's not talk about it, others suffer more despite the fact they are better than me (like the Holy Father John Paul II)". Only at the end, there were moments, when he said: "You have better connections up there[9]*, tell them to take me now".*

[...] He often reiterated that scientific research is very hard and sometimes he would prefer to be a lumberjack, who may rest after the work, being surrounded by a beautiful nature. Nature often lured him to primeval forests and lakes. He documented it in his beautiful photographs and painted pictures.

[...] I think that he rests somewhere among his favourite forests and lakes now but I sometimes miss his words "I haven't seen you for some time, you are getting insubordinate recently Madame Professor".

We close this chapter with some pictures of our meetings with Professor Pawlak.

[9] i.e., in heaven (editor's note).

Fig. 1.33: Professor Pawlak with (from the right) Boris A. Trakhtenbrot, Cecylia Rauszer, wife of Professor Trakhtenbrot and Helena Rasiowa.

Fig. 1.34: Professors Zdzisław Pawlak and Lotfi A. Zadeh.

Acknowledgements

The authors would like to express gratitude to many Colleagues who supported in different ways the preparation of this chapter, in particular to Mohua Banerjee, Andrzej Czyżewski, Piotr Dembiński, Jerzy Fiett, Jerzy Dembczyński, Salvatore Greco, Anna Gomolińska, Wojciech Gomoliński, Andrzej Jankowski, Bożena

Fig. 1.35: Charlotte, 1984; from the left: Professor Pawlak, Viktor W. Marek, Elizabeth Marek, Natalia Marek, Professor Rasiowa.

Fig. 1.36: Professor Zdzisław Pawlak and Hiroakira Ono with wife.

Kostek, Solomon Marcus, Toshinori Munakata, Hung Son Nguyen, Hiroakira Ono, Lech Polkowski, Maria Semeniuk-Polkowska, Zbigniew W. Raś, Grzegorz Rozenberg, Janusz Sosnowski, Urszula Stańczyk, Zbigniew Suraj, Marcin Szczuka, Mirosław Truszczyński, Lotfi A. Zadeh, Wojciech Ziarko.

Fig. 1.37: Professor Pawlak in U.S.A. with (from the right) Anita Wasilewska, Zbigniew W. Raś, Shusaku Tsumoto, Wojciech Ziarko.

Fig. 1.38: With Setsuo Ohsuga: Birthday of Professor Pawlak in Japan.

At the beginning of this article is given only the corresponding author affiliation. Here, we include the affiliations of all other co-authors:

1. Mihir Kr. Chakraborty: Center for Cognitive Science, Jadavpur University, Kolkata 700032, India and Indian Statistical Institute, Kolkata, India, e-mail: mihirc4@gmail.com;

Fig. 1.39: RSCTC 1998.

Fig. 1.40: From trip after FUZZ-IEEE 1998, Anchorage, Alaska; (from the left) Andrzej Czyżewski, Lech Polkowski, Professor Zdzisław Pawlak.

Fig. 1.41: From trip after FUZZ-IEEE 1998, Anchorage, Alaska; (from the left) Professor Zdzisław Pawlak, Bożena Kostek, Lech Polkowski.

Fig. 1.42: On the way to Banff, RSCTC 2000; (from the left) Professor Zdzisław Pawlak, Jerzy Grzymała- Busse, Lech Polkowski and Andrzej Skowron.

Fig. 1.43: On the way to Banff, RSCTC 2000; (from the right) Lech Polkowski, Jerzy Grzymała-Busse with wife Dobroslawa, and Professor Zdzisław Pawlak.

2. Jerzy Grzymała-Busse: Department of Electrical Engineering and Computer Science, University of Kansas, Lawrence, KS 66045, USA and Institute of Computer Science, Polish Academy of Sciences, 01–237 Warsaw, Poland, e-mail: jerzy@ku.edu;
3. Victor Marek: Department of Computer Science, University of Kentucky, Lexington, KY 40506, e-mail: marek@cs.uky.edu;

Fig. 1.44: Visit in Kansas, Professor Zdzisław Pawlak on swing with (Witold and Jan) sons of Jerzy Grzymała-Busse.

Fig. 1.45: Visit in Kansas, Professor Zdzisław Pawlak enjoying activities on swing in Kansas.

4. Sankar K. Pal: Indian Statistical Institute, 203 Barrackpore Trunk Road, Kolkata - 700 108, India, e-mail: sankar@isical.ac.in;
5. James F. Peters: Department of Electrical & Computer Engineering, University of Manitoba, 75A Chancellor's Circle, EITC Room E1-526, Winnipeg, Manitoba, R3T 3E2, Canada, e-mail: jfpeters@ee.umanitoba.ca;
6. Dominik Ślęzak: Institute of Mathematics, University of Warsaw, Banacha 2, 02-097 Warsaw, Poland and Infobright Inc., Krzywickiego 34, lok. 219, 02-078 Warsaw, Poland, e-mail: slezak@{mimuw.edu.pl,infobright.com};
7. Roman Słowiński: Institute of Computing Science, Poznań University of Technology, 60-965 Poznań, Poland e-mail: rslowinski@cs.put.poznan.pl;

Fig. 1.46: Lunch with Professor Zdzisław Pawlak in 2000 during the visit of Sankar K. Pal in Warsaw; (from the right) Sankar K. Pal, Professor Pawlak, Lech Polkowski, and Andrzej Skowron.

Fig. 1.47: Rough Set Theory and Granular Computing (RSTGC 2001), Matsue, Shimane, Japan, May 20-22, 2001; (from the left) Shusaku Tsumoto with family, Sankar K. Pal, Professor Zdzisław Pawlak, Jerzy Grzymała-Busse, Paulina Zalewska and her friend.

8. Alicja Wakulicz-Deja: Institute of Computer Science, University of Silesia, Będzińska 39, 41-200 Sosnowiec, Poland e-mail: `wakulicz@us.edu.pl`;

Fig. 1.48: Professor Zdzisław Pawlak at home with Andrzej Skowron (2000).

Fig. 1.49: Professor Zdzisław Pawlak singing arias at home (2000), (on the right) Sankar K. Pal.

9. Shusaku Tsumoto: Department of Medical Informatics, Shimane University, School of Medicine, 89-1 Enya-cho, Izumo-city, Shimane 693-8501 Japan, e-mail: tsumoto@med.shimane-u.ac.jp;
10. Guoyin Wang: Chongqing University of Posts and Telecommunications, Chongqing, P. R. China 400065, e-mail: wanggy@ieee.org.

The research of Andrzej Skowron has been partially supported by the grant NN516 077837, from the Ministry of Science and Higher Education of the Republic of Poland, the grant 2011/01/D/ST6/06981 from the Polish National Science Centre, the National Centre for Research and Development (NCBiR) under

Fig. 1.50: Christmas 2003: Professor Zdzisław Pawlak and Andrzej Jankowski.

grant SP/I/1/77065/10 by the strategic scientific research and experimental development program: "Interdisciplinary System for Interactive Scientific and Scientific-Technical Information", and under the individual research grant by the program Homing Plus, edition 3/2011, from the Foundation for Polish Science.

References

1. Bar-Hillel, Y., Carnap, R.: An Outline of a Theory of Semantic Information. Research Laboratory of Electronics, Cambridge, MA, *Technical Report* **247**, MIT (1953)
2. Barwise, J. Seligman, J.: Information Flow: The Logic of Distributed Systems. Cambridge University Press (1997)
3. Dembczyński, J.: Introduction. In: Długosz, K. (ed.). Zdzisław Pawlak. Doctor Honoris Causa of Poznań University of Technology, p. 5, Poznań University of Technology, Poznań (2002) (in Polish)
4. Doherty, P., Łukaszewicz, W., Skowron, A., Szałas, A.: Knowledge Representation Techniques: A Rough Set Approach. *Studies in Fuzziness and Soft Computing* **202**, Springer, Heidelberg (2006)
5. Dretske, F.: Knowledge and the Flow of Information. The MIT Press, Cambridge, MA (1981)
6. Ehrenfeucht, A., Peters, J. F., Rozenberg, G., Skowron, A.: Zdzisław Pawlak life and work (1926-2006). Bulletin of the European Association for Theoretical Computer Science (EATCS) **90**, 202–204 (2006)
7. Floridi, L.: Information – A Very Short Introduction. Oxford University Press, Oxford (2010)
8. Floridi, L. (ed.): The Cambridge Handbook of Information and Computer Ethics. Cambridge University Press, Cambridge (2010)

Fig. 1.51: Christmas 2003: Professor Zdzisław Pawlak and Andrzej Skowron.

9. Goldin, D., Smolka, S., Wegner, P.: Interactive Computation: The New Paradigm. Springer, Heidelberg (2006)
10. Head, T.: Formal language theory and DNA: An analysis of the generative capacity of specific recombinant behaviors. Bulletin of Mathematical Biology **49**, 737-759 (1987)
11. Jankowski, A., Skowron, A.: Logic for artificial intelligence: The Rasiowa – Pawlak school perspective. In: Ehrenfeucht, A., Marek, V., Srebrny, M. (eds.), Andrzej Mostowski and Foundational Studies, pp. 106–143, IOS Press, Amsterdam (2008)
12. Joshi, M., Bhaumik, R. N., Lingras, P., Patil, N., Salgaonkar, A., Ślęzak, D.: Rough Set Year in India 2009. In: Sakai, H., Chakraborty, M. K., Hassanien, A. E., Ślęzak, D., Zhu, W. (eds.), Proceedings of the 12th International Conference on Rough Sets, Fuzzy Sets, Data Mining and Granular Computing (RSFDGrC 2009), Delhi, India, December 15-18, 2009, *Lecture Notes in Artificial Intelligence*, vol. 5908, pp. 67–68, Springer, Heidelberg (2009)
13. Marcus, S.: Z. Pawlak a Precursor of DNA Computing and of Picture Grammars. In: Skowron, A. (ed.). New Frontiers in Scientific Discovery – Commemorating the Life and Work of Zdzisław Pawlak. Fundamenta Informaticae **75** (1-4), 331-334 (2007)

Fig. 1.52: Professor Zdzisław Pawlak.

14. Marek, W., Pawlak, Z.: On the foundation of information retrieval. Bulletin of the Polish Academy of Sciences, Ser. Sci. Math. Astronom. Phys. **22** (4), 447–452 (1974)
15. Marek, W., Pawlak, Z.: Information storage and retrieval - Mathematical foundations. Theoretical Computer Science **1**, 331–354 (1976)
16. Munakata, T.: A personal view on AI, rough set theory and Professor Pawlak. Transactions on Rough Sets VI: Journal Subline, *Lecture Notes in Computer Science* **4374**, 247–252 (2007).
17. Pawlak, Z.: Flip-flop as generator of random binary digits. Mathematical Tables and Other Aids to Computation **10** (53), 28–30 (1956)
18. Pawlak, Z.: Do they think, or not? Principles of operation of digital apparatuses. Problemy 77–86 (1956) (in Polish)
19. Pawlak, Z.: Artificial intelligence. Argumenty **7**, 4 (1963) (in Polish)
20. Pawlak, Z.: Organization of address-less computers working in parenthesis notation. Zeitschrift für Mathematische Logik und Grundlagen der Mathematik **9** (1963) 243–249
21. Pawlak, Z.: Grammar and Mathematics. PZWS, Warsaw (1965) (in Polish)
22. Pawlak, Z.: Organization of Address-less Computers). PWN, Warszawa (1965) (in Polish)
23. Pawlak, Z.: On the notion of a computer. In: van Rootselaar, B., Staal J,. F. (eds.), Logic, Methodology and Philosophy of Science III: Proceedings of the Third International Congress for Logic, Methodology and Philosophy of Science, Amsterdam 1967, pp. 255–267, North Holland, Amsterdam (1968)
24. Pawlak, Z.: Another comment on 'negative radix conversion'. IEEE Transactions on Computers (Correspondence) **20**, 587 (May 1971)
25. Pawlak, Z.: Mathematical foundation of information retrieval. In: Proceedings of the International Symposium and Summer School on Mathematical Foundations of Computer Science, Strbske Pleso, High Tatras, Czechoslovakia, 1973, pp. 135–136, Mathematical Institute of the Slovak Academy of Sciences (1973)
26. Pawlak, Z.: About information retrieval. Delta **4**, 12-14 (1975) (in Polish)
27. Pawlak, Z.: Information systems theoretical foundations. Information Systems **6**(3) 205–218 (1981)

28. Pawlak, Z.: Rough sets. International Journal of Computer and Information Sciences **11**, 341–356 (1982)
29. Pawlak, Z.: On conflicts. International Journal of Man-Machine Studies **21**, 127–134 (1984)
30. Pawlak, Z.: Rough Sets - Theoretical Aspects of Reasoning about Data. *System Theory, Knowledge Engineering and Problem Solving* **9**, Kluwer Academic Publishers, Boston, Dordrecht (1991)
31. Pawlak, Z.: Anatomy of conflics. Bulletin of the EATCS **50**, 234–246 (1993)
32. Pawlak, Z.: Thanks. In: Długosz, K. (ed.), Zdzisław Pawlak. Doktor Honoris Causa of Poznań University of Technology, pp. 15–18, Poznań University of Technology, Poznań (2002) (in Polish)
33. Pawlak, Z.: What is next? In: Długosz, K. (ed.). Zdzisław Pawlak. Doctor Honoris Causa of Poznań University of Technology, pp. 21–29, Poznań University of Technology, Poznań (2002) (in Polish)
34. Pawlak, Z.: Some remarks on conflict analysis. European Journal of Operational Research **166**(3), 649–654 (2005)
35. Pawlak, Z., Skowron, A.: Rudiments of rough sets. Information Sciences **177** (1), 3–27 (2007)
36. Pawlak, Z., Skowron, A.: Rough sets: Some extensions. Information Sciences **177** (1), 28–40 (2007)
37. Pawlak, Z., Skowron, A.: Rough sets and Boolean reasoning. Information Sciences **177** (1), 41–73 (2007)
38. Peters, J. F., Skowron. A.: Some contributions by Zdzisław Pawlak. In: Wang, G., Peters, J.F., Skowron, A., Yao, Y. (eds.): Proceedings of the 1st International Conference on Rough Sets and Knowledge Technology (RSKT'2006), Chongqing, China, July 24-26, 2006, *Lecture Notes in Artificial Intelligence*, vol. 4062, pp. 1–11, Springer-Verlag, Heidelberg (2006)
39. Peters, J. F., Skowron. A.: Zdzisław Pawlak life and work (1926-2006). Transactions on Rough Sets V: Journal Subline, *Lecture Notes in Computer Science* **4100**, 1–24 (2006).
40. Peters, J. F., Skowron. A.: Zdzisław Pawlak Commemorating His life and work. In: Greco, S., Hata, Y., Hirano, S., Inuiguchi, M., Miyamoto, S., Nguyen, H.S., Słowiński, R. (eds.): Proceedings of the 5th International Conference on Rough Sets and Current Trends in Computing (RSCTC'2006), Kobe, Japan, November 6-8, 2006, *Lecture Notes in Artificial Intelligence*, vol. 4259, pp. 49-52, Springer-Verlag, Heidelberg (2006)
41. Peters, J. F., Skowron. A.: Zdzisław Pawlak life and work (1926-2006). Information Sciences **171** (1), 1–2 (2007)
42. Polkowski, L., Skowron, A. (eds.): Proceedings of the First International Conference on Rough Sets and Soft Computing (RSCTC 1998), June 22-26, 1998, Warsaw, Poland, *Lecture Notes in Artificial Intelligence*, vol. 1424. Springer-Verlag (1998)
43. Rosenfeld, A.: Picture Processing by Computer. Academic Press, New York – London (1969).
44. Salomaa, A.: Formal Languages. Academic Press, New York – London (1973).
45. Shaw, A.C.: A proposed language for the formal description of pictures. GSG Memo 28, Stanford, California, February 1967, 1-32.
46. Skowron, A. (ed.): New frontiers in scientific discovery – Commemorating the life and work of Zdzisław Pawlak. Fundamenta Informaticae **75** (1-4), 1-562 (2007)
47. Słowiński, R.: Laudatio dedicated to Mr Professor Ph.D. hab. M.Eng. Zdzisław I. Pawlak. In: Długosz, K. (ed.), Zdzisław Pawlak. Doctor Honoris Causa of Poznań University of Technology, pp. 7–11, Poznań University of Technology, Poznań (2002) (in Polish)
48. Słowiński, R.: Prof. Zdzisław Pawlak (1926-2006). Obituary. Fuzzy Sets and Systems **157**, 2419-2422 (2006)
49. Stańczyk, U. (ed.): Adam Mrózek (1948-1999). Institute of Theoretical and Applied Informatics of PAS, p. 13, Gliwice (2009) (in Polish)
50. Vitória, A., Maluszynski, J., Szałas, A.: Modeling and reasoning with paraconsistent rough sets. Fundamenta Informaticae **97** (4), 405–438 (2009)
51. Wakulicz-Deja, A. (ed.): Decision Support Systems volume I. University of Silesia, Katowice (2007), 1–206 (in Polish)

52. Wang, G., Zhang, Q., Huang, H., Ye, D., Hu, Q., Hu, X., Shi, Z., Li, Y., Shang, L., An, L., Sai, Y., Chen, S., Liang, J., Qin, K., Zeng, H., Xie, K., Miao, D., Min, F., Wu, Z., Wu, W-Z., Dai, J.: Research on rough set theory and applications in China. Transactions on Rough Sets VIII: Journal Subline, *Lecture Notes in Computer Science* **5084**, 352–395 (2008)
53. Wang, G., Zhang, Q., Yu, H., Hu, J., Hu, F.: Expressing and processing of uncertain knowledge. International Workshop on Rough Sets: Future Research Directions, June 26-27, 2010, Warsaw. Faculty of Mathematics, Computer Science and Mechanics at Warsaw University
54. http://www.cs.utep.edu/interval-comp/pawlak.html
55. Rough Set Database System http://rsds.univ.rzeszow.pl/