Zdzisław Pawlak as I Saw Him and Remember Him Now

Lech Polkowski

No man is an island, Entire of itself, Every man is a piece of the continent, A part of the main (John Donne)

Abstract Zdzisław Pawlak made an impression on many people including this author due to His openness to new ideas, readiness to discuss them and the spirit of creativity He infused with. In this note, we try to sum up our experiences and also to share what we know about Him and His career on basis of what He said. We touch also some less known achievements of Him.

1 Introduction

Zdzisław was born in 1926 in the city of Łódź, in the centre of Poland. This city was founded on the marsh lands in mid-XIX century as the big centre of weaving and clothing industry, for this reason called the 'Polish Manchester'. Large fortunes were made due to the immense russian market to which most of the production went. The climate of that period is rendered in the movie by Andrzej Wajda 'The Promised Land' ('Ziemia Obiecana' in Polish) made after the novel of the same title by the Nobel laureate Władysław Reymont. Zdzisław was 13 and finished elementary school when the second World War broke out. Łódź was renamed Litzmannstadt and incorporated into Reich and Zdzisław worked in a Siemens factory. After the war He was able to pass maturity exams and He begun studies. Initially, He studied Sinology as something far from ordinary (so he said) but finally graduated from Warsaw University of Technology at the Telecommunication Department in 1951. He was lucky to work in a team building the first computing machine in Poland called GAM-1 and He had some important results like the random numbers generator (1953). It would be very difficult to relate all His achievements but it would be sufficient to mention His positional system for arithmetic with the base of −2, the Pawlak machine—a

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G. Wang et al. (eds.), *Thriving Rough Sets*, Studies in Computational Intelligence 708, DOI 10.1007/978-3-319-54966-8_2

new model of a computing machine, the first model of DNA, and of course the idea of a rough set. It is instructive to trace these achievements and corresponding with them scientific interests. The line goes from the first computing machine GAM-1 in early 50-ties, through the work on a computing machine UMC-1 in the Warsaw University of Technology in the years 1957–1959 based on His arithmetic with the minus 2 base, which actually went to production and some dozens of it were produced and worked for about 10 years. This line of activity was crowned in 1963 by a habilitation thesis ‘Organization of address-less machines’. At that time He became a professor at the Institute of Mathematics of the Polish Academy of Sciences (PAS), He became more involved in theory and His research interests shifted toward mathematical linguistics, semiotics, and scientific information. Especially the last topic proved fruitful as the work on information systems led to the idea of a rough set.

2 DNA

A striking testimony to Zdzisław’s abilities and horizons is His model of DNA, regarded by Professor Solomon Marcus, an eminent specialist in mathematical linguistics, as the first in the literature model of genomic grammar. At the same time it is worthy of noticing that this model was published in a relatively little known at least off Poland series of books, ‘Small Mathematical Library’, published by the State Publisher of School Publications, intended as a more popular and informal in style companion to the very professional ‘Mathematical Library’. The book in question was titled ‘Matematyka i Gramatyka’ (‘Mathematics and Grammar’) [3] and one chapter in it was dedicated to a model of DNA, basically as a model of genetic code which assigns to sequences of nucleic acids sequences of polypeptides. The wider reception of this model was due to the late Professor Solomon Marcus, our friend from Roumanian Academy and the University of Bucharest, who presented this model in English (‘Linguistic structures and generative devices in molecular genetics’) [1]. The basic facts used in the genetic language of Pawlak are: 1. DNA is a double helix built of 4 distinct amino-acids: A(denine), T(hymine), G(uanine), C(cytosine). 2. RNA is a single sequence built of 4 amino-acids: A, G, C, U(racyl). 3. Transcription from DNA to RNA follows the following productions:

$$A \to U, T \to A, G \to C, C \to G.$$

Transcription leads to RNA sequence shorter then DNA sequence. 4. Some convex subsequences of length 3 of RNA are *codons*; they code some amino-acids, hence, a sequence of codons is a code for a sequence of amino-acids—a polypeptide. 5. There are 20 amino-acids genetically valid (though some authors adopt their number as 22). In view of these facts and the one-to-one correspondence between codons and amino-acids genetically functional, Zdzisław Pawlak chose to represent active codons as equilateral triangles with sides labelled 0, 1, 2, or 3 corresponding to the sequence U, A, C, G. The rule for labelling was as follows: the left side of the triangle is labelled x, the base is labelled y, and the right side is labelled z in such a way that $x < y$ and $z \leq y$. This way of numbering produces 20 distinct codons written down in the form of a sequence xyz: 010, 011, 020, 021, 022, 10, 121, 122, 030, 031, 032, 033, 130, 13, 132, 133, 230, 231, 232, 233. We can number those codons from 1 to 20 in the order they are listed. Codons are concatenated according to the following rule in terms of their triangle representations: given already formed chain of codons X we may add to X a new codon b if there is in X a codon a whose side value is equal to the base value of b and no side of b is either a base or a side of any codon in X. For instance, if $X = 232$, then we may add 122. Codons like 020 are *terminal* because they cannot be extended; similarly any chain is terminal if it cannot be extended. The test for being terminal is clearly that each external side of such a chain is valued 0. Terminal chains code *proteins* i.e. terminal polypeptide chains. The Pawlak grammar consists of rules corresponding to triangles representing codons:

1. 1-00	2. 1-01	3. 2-00
4. 2-01	5. 2-02	6. 2-10
7. 2-11	8. 2-12	9. 3-00
10. 3-01	11. 3-02	12. 3-03
13. 3-10	14. 3-11	15. 3-12
16. 3-13	17. 3-20	18. 3-21
19. 3-22	20. 3-23	

We have here some pioneering ideas like tessellations generating grammars, and graph grammars (it is easy to convert the triangle rules into graph (precisely, tree) rules). This simple genomic language projecting deep structure (codons) onto surface structure (proteins) can be regarded as an ancestor to recent results in the era when genomes are being deciphered and reveal extraordinarily complex grammars of relations between deep and surface structures [2].

3 I Meet Zdzisław

Though I knew about His existence and He was in committees for thesis defences of a few of my acquaintances including my wife Professor Maria Semeniuk-Polkowska, yet personally I did not meet Him until 1992 on my return from an American university. He took me into His group working already for about 10 years on His idea of a rough set. Prominent there were already Andrzej Skowron, Cecylia Rauszer, working in the chair of Professor Helena Rasiowa. Zdzisław proposed to investigate the problem of giving a topology to rough set spaces—He said that he tried to interest in this problem some researchers at the Mathematical Institute of the Polish Academy of Sciences but to no avail. I learned from Him that in a short time of about two weeks, Roman Słowiński was going to send to Kluwer a collective monograph on rough sets 'Handbook of Applications and Advances of Rough Sets'. I succeeded in preparing and sending to him the first note 'On convergence of rough sets' [5]. Later, in more quiet conditions, I prepared some works which were published in Bulletin of the Polish Academy of Sciences (PAS) under a common header of 'Morphology of Rough Sets'. In those papers I introduced some metrics in infinite information systems that gave topology to various spaces of rough sets. In this way, I satisfied Zdzisław's wish for a topology for rough sets.

4 Work on Mereology

Zdzisław often mentioned that when working at the Mathematical Institute of PAS, He spent time at the Library, perusing and reading works on foundations of concept and set theories. He also benefitted much from conversations and seminars with Andrzej Ehrenfeucht, the legendary logician and mathematician. When travelling once with Zdzisław to a conference in Alaska, we made a stop at Denver to meet Andrzej Ehrenfeucht at Boulder so I could see the old spirit of those discussions reenacted. Zdzisław mentioned the theory of mereology of Stanisław Le'sniewski. Mereology is a theory of parts of the whole, mentioned already by Aristotle (e.g., in his treatise 'De partibus animalium') and treated by medieval philosophers but given a formal axiomatic scheme by Leśniewski in his 'Podstawy Teoryi Zbiorów' ('Foundations of Set Theory') published in Moscow in 1916, where the author was interned during the first world war. At first glance, mereology is relevant to rough sets as set inclusion is a particular example of a part relation and basic constructs of rough set theory, i.e., approximations are defined by means of inclusion of indiscernibility classes. It was the idea of Andrzej Skowron that we consider something like a degree of containment and I found axioms for this extension called Rough Mereology. Further research led to granular computing, new classifier synthesis methods, applications to robotics and data sets. It is doubtful that all this would be done if not the creative atmosphere and free spirit which enlivened those close to Zdzisław Pawlak.

5 Boundaries

It is evident to all who study rough set idea that the most important notion and most important things that conform to that notion is the notion of a boundary and boundaries of concepts as they witness the uncertainty of the concept. The notion of a boundary has been the subject of investigation by philosophers, logicians, topologists. The latter have had an advantage of a point topology and have defined a boundary as the set of points which have the property that each neighborhood of each of them does intersect the set and its complement, so in a sense, boundary consists of points 'infinitely close' to a concept and its complement, and as a rule, boundary is disjoint to a concept and to its complement, save the case when the concept is 'closed' which means that it does contain its boundary. This is fine when we discuss imaginary boundaries in de dicto context. But the problem arises when we speak of de re boundaries existing in the real world. Typical questions are like the Leonardo question cf. Varzi [9]: 'What (...) divides the atmosphere from the water? It is necessary that there should be a common boundary which is neither air nor water but is without substance, because a body interposed between two bodies prevents their contact, and this does not happen in water with air.' We touch here the problem of impossibility of a precise delineation of the boundary. The response from mathematics could be that in such cases the boundary is a fractal dynamically changing with time. But is this fractal from water particles or from air particles? One can see here the soundness of the rough set approach: things in the world are perceived by means of their descriptions, regardless of the fact that in practical usage, the descriptions are replaced with higher level terms, e.g., 'Mount Everest' is a term describing the highest peak on earth whose description would take many attributes. And, things having the same relation to any other thing are collected in aggregates called 'indiscernibility classes' which among themselves partition the universe of things into disjoint pairwise aggregates. Any concept over this universe faces a dichotomy: either it is built of these aggregates or not. In the first case the concept is unambiguous, i.e., for each thing in the universe, every one can decide whether it falls under the concept or not. In the second case, there are aggregates which do intersect both the concept and its complement and can be ascribed to neither. Such aggregates build the boundary of the concept which is precisely defined and things in it belong to the concept and to its complement in an unambiguous way being collectively responsible for the ambiguity of the concept. We may say that indiscernibility aggregates form parts of boundaries of concepts and of their boundary-less approximations. Returning with this picture to the Leonardo question, we may say that the boundary between water and air is the foam belonging partly to water and partly to air as particles in it are closer one to another than some very small real number. One may say that this approach invented by Zdzisław Pawlak is a specimen of the pointless topology whose more general rendition is the mereotopology, i.e., topology in universa equipped with the 'part of' relation *part(.,.)*. In the generalization of Zdzisław approach, the *granular mereotopology* seems adequate. We say about it cf. Polkowski and Semeniuk-Polkowska [6].

5.1 A Granular Mereotopological Model of Boundary as a Direct Generalization of Zdzisław Pawlak's Approach

Mereology is based on the notion of a part relation, $part(x, y)$ ('x is a part to y') which satisfies over a universe U conditions: M1: For each $x \in U$ it is not true that $part(x, x)$ M2: For each triple x, y, z of things in U if $part(x, y)$ and $part(y, z)$, then $part(x, z)$. The notion of an *element* is defined as the relation $el(x, y)$ which holds true if $part(x, y)$ or $x = y$. For our purpose in this section, we modify our approach to mereology. We introduce a new version of rough mereology whose basic notion is predicate 'a part to a degree', $\mu(x, y, r)$, ('x is a part to y to a degree of r at least') on a universe U, where $r \in [0, 1]$. Conditions for μ are RM1 $\mu(x, x, 1)$; RM2 There is a partition on U such that $\mu(x, y, 1)$ and $\mu(y, x, 1)$ if and only if x and y are in the same partition class; RM3 If $\mu(x, y, 1)$ and $\mu(z, x, r)$ then $\mu(z, y, r)$; RM4 If $\mu(x, y, r)$ and $s < r$ then $\mu(x, y, s)$. The predicate $el(x, y)$ if $\mu(x, y, 1)$ defines x as an *element of y*. In the case when U is the universe of an *information system* (U, A) in the sense of Pawlak, with A the set of *attributes*, a predicate μ can be derived from Archimedean t-norms, the Łukasiewicz t-norm $t_L(x, y) = max\{0, x + y - 1\}$ and the Menger t-norm $t_M(x, y) = x \cdot y$, which admit a Hilbert-style representation $t(x, y) = g(f(x) + f(y))$, by letting $\mu^t(x, y, r)$ if and only if $g(\frac{card(Dis(x,y))}{card(A)}) \geq r$, where $Dis(x, y) = \{a \in A : a(x) \neq a(y)\}$. In particular, the *Łukasiewicz rough inclusion* $\mu^L(x, y, r)$ if $\frac{card(Ind(x,y))}{card)A)} \geq r$ satisfies RM1–RM4 with the corresponding relation induced on U partitioning the set U into indiscernibility classes, as $f(x) = 1 - x = g(x)$ for the t-norm t_L, where $Ind(x, y) = A \setminus Dis(x, y)$. The predicate μ^L satisfies the transitivity property: $\mu^L(x, y, r)$ and $\mu^L(y, z, s)$ imply $\mu^L(x, z, t_L(r, s))$. Hence, the corresponding element predicate el satisfies properties $el(x, x)$, $el(x, y)$ and $el(y, z)$ imply $el(x, z)$, $el(x, y)$ and $el(y, x)$ imply x and y are indiscernible. For a predicate μ, and $x \in U$, $r \in [0, 1]$, we define a new predicate $N(x, r)(z)$ if there exists an $s \geq r$ such that $\mu(z, x, s)$. $N(x, r)$ is the *neighborhood granular predicate about x of radius r*. Consider a predicate Ψ on U having a non-empty meaning $[\Psi]$. The *complement to* Ψ is the predicate $-\Psi$ such that $-\Psi(x)$ if not $\Psi(x)$. We define the *upper extension of* Ψ *of radius r*, denoted Ψ_r^+ by letting $\Psi_r^+(x)$ if there exists z such that $\Psi(z)$ and $N(x, r)(z)$. Similarly, we define the *lower restriction of* Ψ *of radius r*, denoted Ψ_r^- by letting $\Psi_r^-(x)$ if not $(-\Psi)_r^+(x)$. A predicate *Open* is defined on predicates on U and a predicate Φ on U is *open*, $Open(\Phi)$ in symbols if $\Phi(x)$ implies the existence of r such that $N(x, r)(z)$ implies $\Phi(z)$. We observe that $\Psi_r^+(x)$ and $\mu(x, y, 1)$ imply $\Psi_r^+(y)$, hence for *symmetric* μ (such is for instance μ^L), the predicate Ψ_r^+ is open. By duality, the complement to an open predicate is *closed*. Hence, the predicate Ψ_r^- is closed for symmetric μ. By symmetry, both predicates are open-closed for a symmetric μ. We say after Barry Smith that a granular neighborhood predicate $N(x, r)$ *straddles* a predicate Ψ if there exist y, z such that $\Psi(y)$, $(-\Psi)(z)$, $N(x, r)(y)$, and, $N(x, r)(z)$. We define the *boundary predicate Bd* on predicates on U. For a predicate Ψ, we define the boundary of Ψ, $Bd(\Psi)$ by letting $Bd(\Psi)(x)$ if each granular neighborhood predicate $N(x, r)$ straddles Ψ, equivalently, the granular neighborhood predicate $N(x, 1)$ straddles Ψ. Please observe that the boundary of Ψ is the boundary of $-\Psi$. Also, for the predicate μ^L, the boundary of Ψ is the rough set boundary, as $\mu^L(x, y, 1)$ is symmetric and partitions U into indiscernibility classes. Further results on boundaries and mereology may be found in [7, 8].

6 A Man of Many Trades

Our tale would be incomplete if we would not mention how many-talented He was. He was an accomplished tourist, in summer rowing in a kayak on rivers and lakes of Polish Pomerania and Mazury, in winters on skis in the mountains. Some 13 years ago my wife has an exhibition of her paintings in the headquarters of the Polish Tourist Organization, we also exhibited photographs submitted by Zdzisław from His trips in the 50-ties. These pictures made a sensation among people present as nobody expected that in those years such trips were possible. He with some colleagues wandered through Bieszczady montains, at that time completely desolate and wild after the second world war. He told us how once in winter in Beskidy mountains he got lost in the blizzard and only by good luck spotted lights of a mountain hostel to be saved. He was a gifted photographer: His photo 'The Polish Jungle' got a distinction at the Times of London photo conquest in 1950-ties. In later years He started painting and had exhibitions of his paintings. He painted what He liked most: water, soil, greenery, and mountains. His paintings are free of human silhouettes, animals, any form of life, He was it seems interested solely in nature's symbiosis of elements. Maybe He posed to Himself the Leonardo question about the boundary between water and air, He so often painted the two. Or, He rendered the idea of rough set in painting? With water He was in a special relation; in addition to making kayak trips and short excursions, He used to swim almost every day. In Warsaw, He used to go to the Academy of Physical Education located close to His home to the swimming pool. The same happened in hotels, every morning at six He went to a swimming pool. But He was also a carpenter, a mason as He renovated His villa in Bielany, a district of Warsaw, making a fireplace etc. pushing a wheelbarrow with lime, mortar and bricks. He told us how He went through antique shops and also read advertisements on old furniture sales to find antique furniture which He renovated. His home was equipped with those pieces of furniture. He was an indestructible voyager; in any place we were, I observed that He wanted to see everything interesting around including a perusal of a local telephone directory to find people by name of Pawlak. Usually He succeeded. He was always full of practical solutions to sudden problems. Once, when my wife had a painting exhibition at some gallery, He was also supposed to come to the opening. Unfortunately, shortly before the appointed hour, when we already were in the gallery, there came a torrential rain so we started without Him convinced that He would not come. But after some twenty minutes he appeared: He bought some newspapers and put them under the jacket so He was underneath dry. There are people who can do almost everything and do it best. He with no doubt belonged to this class. Speaking a bit on jocular side, if Arthur Conan Doyle lived in the second half of the XXth century and knew Zdzisław, He would undoubtedly model his detective on Zdzisław. After all both were masters in deduction.

7 Conclusion

He is not with us of course, but His spirit is I think with those who knew Him. By creating rough sets and making them accepted by the scientific world He gave new life to notions of old, useful but lacking a deeper semantic value, and in doing this He revealed His talent for a clear vision of ideas and ability to represent them in simple understandable to many ways. The success of His monograph on rough sets [4] is due not only to the popularity of rough sets but also to an exceptional combination of theoretical considerations with practical thinking. This seems to be characteristic of His style, avoiding abstraction and keeping in mind practice of application. This is why He was so appealing to many readers. He combined in an exceptional degree the ability to theorize with practical talents and energy to use those abilities and talents.

Acknowledgements To all who knew Zdzisław and enjoyed His goodwill: thanks for not forgetting [6].

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http://www.springer.com/978-3-319-54965-1

Thriving Rough Sets
10th Anniversary - Honoring Professor Zdzisław Pawlak's Life and Legacy & 35 Years of Rough Sets
Wang, G.; Skowron, A.; Yao, Y.; Ślęzak, D.; Polkowski, L. (Eds.)
2017, X, 439 p. 52 illus., 19 illus. in color., Hardcover
ISBN: 978-3-319-54965-1