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Review

PROFESSOR ČUPONA AND THE DEVELOPMENT OF COMPUTER SCIENCE IN MACEDONIA

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This paper reviews the contribution of Professor Čupona in development of Computer Science in Macedonia. The approach taken preserves history, and all events are listed with order of time. The approach also preserves the worldwide context of Computer Science in which development of Computer Science in Macedonia took place. The approach also looks for pioneering contribution of Macedonian Computer Science in the world and the role of Čupona in them. The paper emphasizes the role of Čupona in the first paper in Computer Science written in Macedonian language. Working on Čupona's contribution this research looks also for contributions of the Mathematical Institute with Numeric Center (MINC) and points out a worldwide contribution by this institution. The paper also points out Čupona's work as mathematician, on algebraic structures, and the influence of that work in education and research of Macedonian Computer Science.

Key words: Professor Čupona, development of computer science, Macedonia 1964–2017

INTRODUCTION

This invited paper is a personal view of the author of both the contribution of Professor Gjorgji Čupona and the development of Computer Science in Macedonia. The approach taken in this review is a research in history of Computer Science in Macedonia, preserving years when events happened. The approach also preserves the worldwide context of Computer Science in which development of Computer Science in Macedonia took place. The paper makes a research on Čupona's contribution as visionary, organizer, educator and inspirer of development of Computer Science, as science in Macedonia.

In the sequel we first observe the role of Dr. Čupona in mathematics competitions and nurturing the high school talent. Then we give information about a scientific event, appearance of a book on cybernetics by Glushkov, which inspired Dr. Čupona to determine the direction of development of Computer Science in Macedonia and initiate the first paper on Computer science written in Macedonian language. Then we point out the engagement of Dr. Čupona in building a scientific infrastructure, the Mathematics Institute with Numeric Center (MINC). Then we mention some pioneering results in development of computer science in Macedonia. The educational influence of Čupona as mathematician especially in the field of algebraic structures on education and research on Computer Science in Macedonia is also mentioned.

1960's: HIGH SCHOOL COMPETITIONS IN MATHEMATICS IN MACEDONIA. FIRST MEETING WITH DR. ČUPONA

Many high school students in 1960's met Dr. Čupona for the first time during preparations for mathematics competitions. Here we will mention a generation of mathematics competitors including Smile Markovski, Dimitar Altiparmakov, Tome Mickovski, Risto Ciconkov, Biljana Arsova, Eli Delidzakova, Gjorgi Josifovski, Stevo Božinovski, among many others. Here we will also mention the ”idols” Smilka Zdravkovska and Viktor Urumov, who achieved to participate at the International Mathematical Olympiad in Moscow. Three of the mentioned, same generation students, Dimitar, Smile and Stevo, participated at the federal competitions in Belgrade. The system of organized work with high school students included high school

mathematics professors who worked with students preparing them for the competitions. One such example was Gorica Ilieva, the spouse of Professor Čupona. She had dear personality and knowledge to attract students towards mathematics. The author had a privilege and a pleasure to be one of those students.

Part of preparation for mathematics competitions were various mathematics schools organized by Dr. Čupona. During those activities the interested high school students were exposed to mathematics lectures beyond standard high school curriculum. For example, at that time the concept of a set was not in a regular high school mathematics curriculum. It was taught in those extracurricular activities, along with determinants, matrices, etc. The instructors at the mentioned mathematics schools were university professors, for example Naum Celakovski, Živko Madevski, Aleksandar Samardziski, Branko Trpenovski, among others.

The first meeting between this author and Dr. Čupona happened in 1965 when Gorica Ilieva sent this author to meet Dr. Čupona at the department of Natural Sciences and Mathematics. Not knowing the room number this author went to the library and asked a person how to find Professor Čupona. The person answered with room number and pointed a time later when Dr. Čupona will be there. This author went there at the given time, and a surprise, the person he met before in the library was actually Dr. Čupona. Many years later this author would learn from animal learning theory that according to Rescorla and Wagner, systems learn only when they are surprised. That is how a close collaboration started.

1960's: THE VISION OF PROFESSOR ČUPONA: DEVELOPMENT OF AN INSTITUTION RELATED TO COMPUTERS

During 1960's, worldwide and in Macedonia there was thinking how to guide a development related to computers and programming. Here we point out the vision of professors Gjorgi Čupona and Blagoj Popov who in 1966 formed a Mathematical Institute with Numerical Centre (MINC). It was established as an institution with special interest for the society. We recognize that it was the first institution in Macedonia which in its title had something related to computer science. The second institution who made such a movement was Electro-mechanical Faculty, which in 1972 established a Cathedra of Cybernetics, led by Professor Pane Vidinčev.

One may view that there is no significant difference of 6 years, but in this case there is. In those 6 years some events happened in the world and in Macedonia that influenced the path for the development of Computer Science in Macedonia.

1964: A WORLDWIDE: EVENT IN COMPUTER SCIENCE: A BOOK BY GLUSHKOV

At the time MINC was formed, an important event in science turned out to be influential in the development of Computer Science in Macedonia. In 1964 the book "Introduction to Cybernetics" by Viktor Glushkov appeared [1] offering a radical new view toward Cybernetics. While the previous view was related to control theory, the new book introduced Cybernetics as Computer Science, through theory of algorithms, languages, automata, and self-organizing systems. Here is the chapters overview:

1. The abstract theory of algorithms
2. Boolean functions and propositional calculus
3. Automata theory
4. Self-organizing systems
5. Electronic digital computers and programming
6. The predicate calculus and the automation of the processes of scientific discovery

Glushkov starts with the concept of algorithms in terms of machines by Post, Turing, and Markov, as well as knowledge on propositional calculus. The book then elaborates on automata theory. Basing on automata concept, the book has important contribution to the theory of self-organizing systems. The knowledge of computers and programming is necessary, and book covers the programming language ALGOL. It also covers the predicate calculus and automated reasoning, which is a topic of classical Artificial Intelligence. It gives algebraic treatment of most of the topics covered. The book brought ideas from other researchers in the field of learning for pattern recognition, for example from Rosenblatt and his neural network named Perceptron [2, 3] and Selfridge and his pattern recognizing architecture named Pandemonium [4]. It contained also the newest research of Glushkov himself on abstract automata and self organizing systems [5].

1967 AND 1969: THE CONTEXT: ABSTRACT AUTOMATA WORLDWIDE

To consider the context of development of Computer Science in Macedonia, we will now observe the worldwide development of automata theory through two significant books published in 1967 and 1969.

Although theories of abstract automata were developed in 1950' [e.g. 6], after the Glushkov's treatment of automata theory, two other books relevant to Computer Science in Macedonia, were published.

In 1967 appeared a book by Marvin Minsky with a title "Computation: Finite and Infinite Machines" [7]. To see an influential view on automata theory at that time, here we list its chapters.

Part I: Finite state machines

1. Physical machines and their abstract counterparts.
2. Finite state machines
3.Naural networks: automata made up of parts
4. Memories of events in finite state machnes

Part II. Infinite machnes

5. Computability, effective procedures, and algorithms
6. Turing machines
7. Universal Turing machines
8. Limitations of effective computability: some problems not solvable by instruction-obeying machiens
9. Computable real numbers
10. The relation between Turing machines and recursive functions
11. Models similar to digital computers

Part III. Symbol manipulation systems and computability

12. Symbol manipulation system by Post
13. Post's normal form theorem
14. Very simple bases for computability

In 1969 appeared a book by Michael Arbib entitled "Theories of Abstract Automata" [8]. The list of chapters is

I Background

1. An overview of automata theory
2. Algebraic background

II An introduvtion to automata theory

3. Finite automata
4. Turing machines and effective computation
5. Post system and context-free languages

III Selected topics

6. Partial recursive functions
7. Complexity of computation
8. Algebraic decomositon theory
9. Stochastic automata
10. Machiners which copute and construct

1968: THE BOOK BY GLUSHKOV AS AN INSPIRATION FOR PROFESSOR ČUPONA

At this point we observe a context of development of Computer Science in the world in the field of abstract automata, and in Macedonia we observe an effort of Dr. Čupona to develop something related to mathematics and computers. Here comes the book of Glushkov.

The Glushkov's book was translated in several languages, for example in USA it was translated in 1966 [9]. In Yugoslavia it was translated by Rajko Tomovic and Momcilo Uscumlic in 1967 [10]. The book was presented at the Book Fair in Skopje. At that time the Fair was in old location on the left bank of river Vardar. Important coincidence was that at that Book Fair the Glushkov's book was purchased by Dr. Čupona, and, independently, by the author of this paper. The cover of this book is shown in Figure 1.

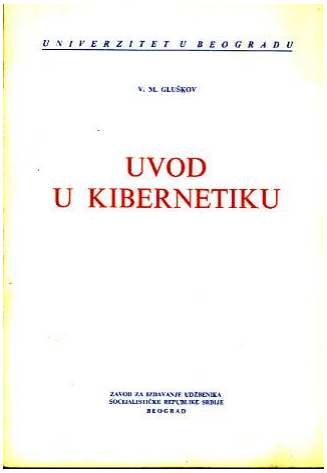


Figure 1. The book which inspired Professor Čupona to guide the development of Computer Science in Macedonia

The visionary Dr. Čupona realized that the abstract automata theory is the way to go for development of a computer science. His spouse Gorica Ilieva was mathematics teacher of the author of this text. The year 1968 was the year when this author had to choose a topic of his high school (matural) thesis. One day Gorica Ilieva brought the book by Glushkov and showed it to this author and proposed that the chapter on abstract automata be the Matural Thesis in mathematics. The author of this text said that he is accepting the proposal, but he does not need the book, because he had already purchased it at the Book Fair. That way Dr. Čupona learned about the coincidence of purchasing the same book with this high school student.

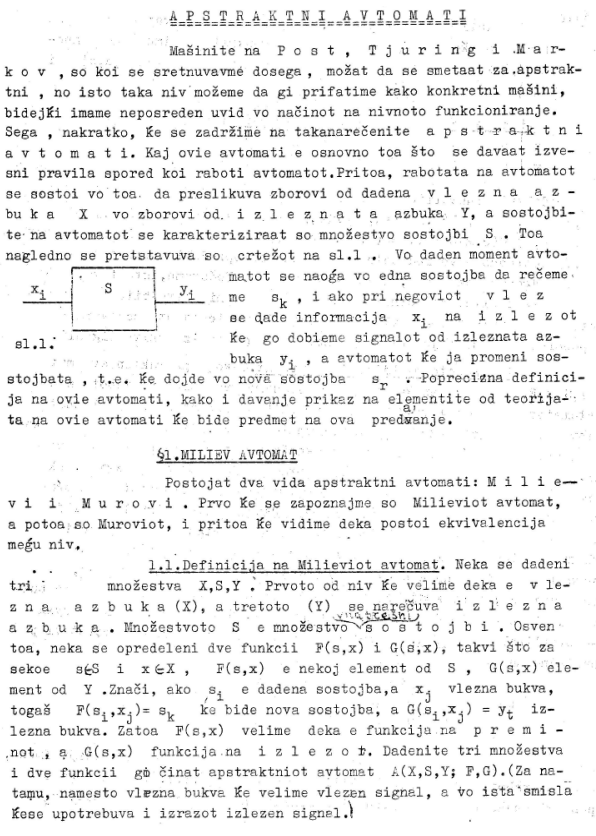
So, a work started of studying the automata theory by a high school student, and Glushkov became his teacher. During this period Dr. Čupona was interested to see the progress of the work. While the supervisor of the Matural Thesis was Professor Gorica Ilieva, many discussions with Dr Čupona were on the topic.

Having a vision of the development of mathematics, computer science and cybernetics, Dr. Čupona decided to organize a seminar on cybernet-

ics motivated by the book of Gluskov. In 1968 professor Čupona organized the First Seminar on Cybernetics in Macedonia. He used the first three chapters of the Glushkov's book to be guidelines for the seminar.

Nine lectures were presented by university professors at the seminar including Naum Celakoski, Branko Trpenovski, Živko Madevski, Aleksandar Samardziski, and Gjorgji Čupona. He also invited lecturers related to cybernetics from standpoint of control theory (Pane Vidinčev) as well as from standpoint of biology (Lav Lozinski).

At that time there was no university instructor in Macedonia working on abstract automata. But there was a high school student who already wrote his high school thesis entitled Abstract Automata. Considering all that, Professor Čupona decided that the 10th lecture of the seminar will be on abstract automata and will be delivered by the high school student who already had knowledge of the subject. The lecture was written by this author as a handout paper, reproduced on schapyrograph (a copying technology of that time), The paper was edited by Dr. Čupona. It was distributed among the participants of the seminar in May 1968. The first page of the paper [11] is shown in Figure 2.



A P S T R A K T N I A V T O M A T I

Mašinite na P o s t , T j u r i n g i M a r k o v , so koi se sretnuvavme dosega , možat da se smetaat za apstraktni , no isto taka niv možeme da gi prifatime kako konkretni mašini, bidejḱi imame neposreden uvid vo načinot na nivnoto funkcioniranje. Sega , nakratko, ḱe se zadržime na takanarečenite a p s t r a k t n i a v t o m a t i. Kaj ovie avtomati e osnovno toa što se davaat izvesni pravila spored koi raboti avtomatot. Pritoa, rabotata na avtomatot se sostoi vo toa da preslikuva zborovi od dadena v l e z n a a z b u k a X vo zborovi od i z l e z n a t a azbuka Y, a sostojbite na avtomatot se karakteriziraat so množestvo sostojbi S . Toa nagledno se pretstavuva so crtežot na sl.1 . Vo daden moment avtomatot se naoǵa vo edna sostojba da rečeme me s_k , i ako pri negoviot v l e z se dade informacija x_i na i z l e z ot ḱe go dobieme signalot od izleznata azbuka y_i , a avtomatot ḱe ja promeni sostojbata , t.e. ḱe dojde vo nova sostojba s_r . Poprecizna definicija na ovie avtomati, kako i davanje prikaz na elementite od teorijata na ovie avtomati ḱe bide predmet na ova predavanje.

sl.1.

§1.MILIEV AVTOMAT

Postojat dva vida apstraktni avtomati: M i l i e — v i i M u r o v i . Prvo ḱe se zapoznajme so Milieviot avtomat, a potoa so Muroviot, i pritoa ḱe vidime deka postoi ekvivalencija meǵu niv.

1.1.Definicija na Milieviot avtomat. Neka se dadeni tri množestva X,S,Y . Prvoto od niv ḱe velime deka e v l e z n a a z b u k a (X), a tretoto (Y) se narečuva i z l e z n a a z b u k a . Množestvoto S e množestvo s o s t o j b i . Osven toa, neka se opredeleni dve funkcii F(s,x) i G(s,x), takvi što za sekoe s∈S i x∈X , F(s,x) e nekoj element od S , G(s,x) element od Y .Znači, ako s_i e dadena sostojba,a x_j vlezna bukva, togaš $F(s_i,x_j)= s_k$ ḱe bide nova sostojba, a $G(s_i,x_j) = y_t$ izlezna bukva. Zatoa F(s,x) velime deka e funkcija na p r e m i n o t , a G(s,x) funkcija na i z l e z o t. Dadenite tri množestva i dve funkcii gi činat apstraktniot avtomat A(X,S,Y; F,G).(Za natamu, namesto vlezna bukva ḱe velime vlezen signal, a vo ista smisla ḱe se upotrebuva i izrazot izlezen signal.)

Figure 2. Beginning of the first paper in Computer Science in Macedonia written by Macedonian language. It contains a handwritten editing note by Professor Čupona.

We would point out that a review of applicability of automata theory is given in a previous paper devoted to Professor Čupona in 2010 [12].

THE IMPORTANCE OF THE 1968 PAPER

This paper shows the vision of Professor Čupona toward the development of mathematics, computer science, and cybernetics in Macedonia, that it should include automata theory and related topics. This paper marks the start of Computer Science in Macedonia.

Dr. Čupona introduced abstract automata in Macedonia in 1968, between the 1967 book of Minsky and 1969 book of Arbib. The Čupona's effort was on time, enabling the Macedonian science to catch up with development of Computer Science in the world.

Dr. Čupona inspired a high school student to write the first paper on Computer Science in Macedonian language. He created a student who was well educated and competing in mathematics, and now he already studied automata theory and related topics from a teacher such as Viktor Glushkov. Reading the book, the student viewed the next chapter after automata theory, which was on perceptrons, machine learning, and related topics in Artificial Intelligence. In addition to that, Dr. Čupona brought the student to the home of Lav Lozinski. The three of them, in Professor Lozinski's room, filled with piles of books on the floor, discussed about application of mathematics in biology.

The formal organizer of the 1968 seminar was MINC. It was one of contributions of this institution to development of Computer Science in Macedonia.

1969: A WORLDWIDE EVENT. THE BOOK OF MINSKY AND PAPERT

Two years after his book on abstract machines, Minsky decided to give contribution to pattern recognizing learning machines, and in 1969 a book appeared by Marvin Minsky and Seymour Papert named "Perceptrons" [13]. This book points some limitations of perceptrons. By many AI reserchers it was interpreted as neural network research is not promising. Because Minsky was very influential name in Computer science, the National Science Foundation (NSF) of USA stopped financing the artificial neural networks research.

In that worldwide context, after the 1968 lecture and paper, this author continued his study at the Electrical Engineering department (ETF) of University of Zagreb. At ETF Zagreb, this author

looked for opportunity to work on chapter IV of the Glushkov's book, self-orgnizing systems. In 1971 University of Zagreb opened a competition for a student scientific work, named 1st of May Prize. This authot went to Professor Ante Santic who was the only professor having the word perceptrons in his syllabi. Dr Santic gave a support, and the paper was written [14], entered the competition, and was awarded by the university Rector, Professor Ivan Supek. More importantly, perceptrons and machine learning were now already studied by this author. Also, the first software was written, in Fortran language, to simulate the learning process of a perceotrion in recognizing patterns on a binary retina.

Regarding the book of Minsky and Papert, this author read it at that time, 1971, in Zagreb, in Russian translation. From reading the book, for this author it did not seem evident that the neural networks are not a promising direction, and he decided that he will continue his research on neural networks and related topics.

In the meantime, in 1971 ETF in Zagreb opened the first undergraduate computer science program in Yugoslavia. This author was the first generation students of that program.

A series of works followed on neural networks. An undergraduate seminar work on digital integrated circuit (DTL technology) simulating a neural network for conditioned reflex [15], was the first work on simulation a neural network in hardware. It was used later in a textbook by Professor Santic [16, Fig. 1, 28]. The undegraduate Diploma Thesis was on simulation of neural elements with both impulse (astable multivibrator) and digital electronics [17]. The Master's Thesis was on software simulation of perceptroms for pattern recognition. [18].

So, despite the view of Minsky and Papert [13], this author continued working on neural networks believing that neural networks approach is very promising.

1974–76: MINC: APPLICATIVE COLLABORATION WITH OTHER INSTITUTIONS

In 1974 the author of this text joined the Mathematical Institute with Numerical Centre (MINC).

Since 1968 this institution has grown significantly. The directors of MINC were B. Popov (1966–1969), G. Čupona (1969–1973), I. Šapkarev (1973–1975), and Ž. Madevski (1975–1977).

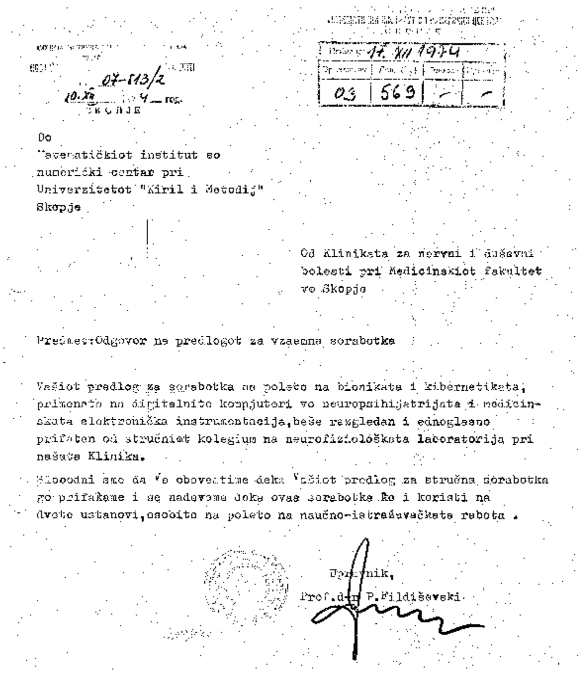
By 1976 MINC employed 16 people from various disciplines, including mathematicians, electrical engineers, computer scientists, and economists. Here is the list of scientists engaged by MINC with years of their employment:

S. Zdravkovska, S. Ivanov, J. Hadzi-Pecov (1969), T. Šurležanovska (1970), R. Šokarovski, D. Korobar Tanevska, N. Sekulovska, Lj. Stefanova (1971), V. Naumovska , V. Kusakatov (1972), D. Mihajlov, D. Nikolic, M. Kon-Popovska, V. Naumovska (1973), S. Božinovski, M. Simova (1974), D. Dimovski (1976).

The Institute also had external collaborators, people employed in other institutions.

MINC engaged in two directions, applicative and scientific. Because MINC was a creation of Dr. Čupona, here we will mention the applicative and scientific work undertaken within MINC by this author.

The first applicative work was a collaboration between MINC and Clinic of Neuropsychiatry. Figure 3 shows the collaboration agreement.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Do
Matematičkiot institut so
numerički centar pri
Univerzitetot "Kiril i Metodij"
Skopje

Od Klinikata za nervni i duševni
bolesti pri Medicinskiot fakultet
vo Skopje

Predmet:Odgovor na predlogot za vzaemna sorabotka

Vašiot predlog za sorabotka na poleto na bionikata i kibernetikata, primenata na digitalnite kompjutori vo neuropsihijatrijata i medicinskata elektronička instrumentacija,beše razgledan i ednoglasno prifaten od stručniot kolegium na neurofiziološkata laboratorija pri našata Klinika.

Slobodni sme da Ve obvestime deka Vašiot predlog za stručna sorabotka go prifakame i se nadevame deka ovaa sorabotka ke i koristi na dvete ustanovi,osobito na poleto na naučno-istražuvačkata rabota .

Upravnik,
Prof.d-r P.Fildiševski

Figure 3. The collaboration agreement between MINC and Clinic of Neuropsychiatry, 1974

The collaboration was established by letters from directors of both institutions, by Professor Ilija Šapkarev for MINC and Professor Petar Fildisevski for the Neuropsychiatric Clinic. It was the first applicative formal collaboration of MINC with another institution. The collaboration with this clinic enabled working with section for biosignals, especially EEG. The first teacher to this author about reading an EEG was Dr. Liljana Dzambaska, but collaboration was carried out also with Dr. Aleksandar Naumovski and Dr. Vera Ivanova.

Next collaboration was established with Zavod for Mental Health of Children and Youth. Collaboration was established on the project for growth and development of the children in the first three years. It was a project supported by USA, and project representative was Professor Robert Reed, from Department of Biostatistics, Harvard School of Public Health. Two people were engaged from MINC, the author of this text and Simova Marija. They worked on processing the Binet-Simon scale. Collaborators from the other institution were Ruzica Keramitcieva and Sineva Joveva.

Another collaboration was established in 1976 with Institute of Physiology led by director Professor Vanco Kovacev. It was for the project on physical and functional characteristics of the population in Macedonia. A database was built containing 150,000 entries. The author of this paper worked together with Margita Kon-Popovska. This project brought the first payment to MINC for its applicative engagement.

1976: MINC: THE FIRST MACEDONIAN WORLDWIDE ACHIEVEMENT IN COMPUTER SCIENCE

Although applicative work was encouraged by MINC, the scientific work was its primary focus. Three papers of this author are mentioned here:

In 1975 a paper was published in the Review of Psychology which was printed in Zagreb, and was about abstract automata and neural networks [19]. The pioneering scope of this paper is local, it is the first Artificial Intelligence journal paper by a Macedonian author.

The second paper was a local paper entitled "An approach toward threshold elements and formal neurons" [20] and was actually a presentation for MINC about the research in neural networks carried out at MINC. The presentation advisor was Smilka Zdravkovska.

The third was a pioneering paper published in 1976 as a conference paper. It was entitled "Influence of pattern similarity and transfer of learning on the training the base perceptron B2" [21]. Many years later it was realized worldwide that transfer learning is important concept of Machine Learning. The second paper of the topic was published in USA in 1991 fifteen years after this pioneering paper [22]. This paper written by an employee of MINC in 1976 is now cited in historical part of the Wikipedia topic on transfer learning [23, 24]. This achievement of MINC is due to engagement of Dr Čupona and the 1968 paper.

It is important to mention a 1976 work of Professor Čupona. Being great supporter of development of MINC and Computer Science in Macedonia, he also remained primarily professor of mathematics. In 1976 he published his textbook "Algebraic Structures and Real Numbers" [25]. Later it will become relevant to education of Computer Science in Macedonia.

1977−1979: ČUPONA'S WORK ON COMPUTER SCIENCE EDUCATION THROUGH MATHEMATICAL SCHOOLS

Professor Čupona was engaged in Mathematical Schools for education of students interested in mathematical competitions through mathematical summer schools. After 1968 he realized that computer science education should be applied at level of the summer mathematical schools. At that time, at the end of 1976, this author joined the Cathedra of Cybernetics of the Electro-mechanical Faculty. He started teaching as teaching assistant the subject of digital computers following the book of Branko Souček, who was his professor of computers and processes at the University of Zagreb.

In 1977 Professor Čupona was organizing a mathematical school in Ohrid, and he asked this author to carry out a mathematical school providing deeper knowledge than the standard Fortran programming. A 44-page booklet was prepared [26] to support teaching the relation between computer hardware and software as well as programming at the machine level.

1979–1981: FOLLOWING THE VISION OF DR. ČUPONA, JOINING A MILITARY RESEACH ON NEURAL NETWORKS IN USA

In 1979 two events happened which highly influenced development of Computer Science in Macedonia and in the world.

First, the author of this text applied for a Fulbright scholarship. He met Dr. Arbib at a conference in Bled and asked him if he is interested in neural networks research. Arbib said that the author should apply to his institution, University of Massachusetts at Amherst.

The second event was related to the context created by the book of Minsky and Papert. In 1979 there was no federal funding of artificial neural networks research. However, the Air Force base in Dayton, Ohio, decided that artificial neural networks research is needed, and decided to finance itself such a research. They opened a project at the University of Massachusetts at Amherst in 1979 at

the time the author of this text asked Arbib to work on neural networks. Arbib recommended contact with Professor Nico Spinelli, who was the leader of the group, named Adaptive Networks (ANW) group carrying out the project. So, the author of this paper was accepted to work on a military funded project on neural networks.

Observing this event, we can see that the vision of Dr. Čupona created a student who is now proficient in theory and programming of neural networks and is part of USA military project on that topic. So, the firm belief of this author in neural networks, rather than the common belief that those are "weak methods" in Artificial Intelligence, paid off. The vision of Dr. Čupona now reached the worldwide science.

Having both theoretical and programming knowledge of neural networks this author was able to produce significant pioneering results. Some of them are introduction of the concept of self learning (besides supervised and reinforcement learning) and, introduction of emotion in neural network learning, introduction of genetics in neural networks learning, the solution of the problem of reinforcement learning with delayed rewards, among others [27–30]. Those are results of the knowledge gained from the Čupona's 1968 vision. It should be mentioned that direction and the challenges related to reinforcement learning was defined by Adaptive Networks (ANW) group which carried out the project (in 1981: Spinelli, Arbib, Barto, Sutton, Anderson, Porterfield, Bozinovski). However, the self-learning research direction, based on emotion and genetics, was determined by the author of this text.

In 1986 a book appeared by David Rumelhart, Jay McClelland, and the parallel distributed processing group entitled "Parallel Distributed Processing" [31]. It basically said that the neural networks research is indeed promising. So, NSF started again financing such research, and neural networks research become a mainstream in Artificial Intelligence.

1982–1989: MORE PIONEERING RESULTS BY THE MACEDONIAN COMPUTER SCIENCE

During 1982–1988 the author stayed in intensive contact with Dr Čupona. Each year since high school he visited his home for the birthday of Professor Gorica Ilieva. Many times, this author and Dr. Čupona hiked on mountain Vodno. One was night hiking over Vodno to the water spring above village Sopiste. A hike took place on mountain Skopje's Montenegro, Dr. Čupona was always informed and interested in the work of this author.

Several worldwide pioneering results happened in this period and here will be mentioned two of them.

In 1986 the first speech-controlled robot was built in Macedonia [32, 33]. A robot was controlled by the following commands: "trgni", "nazad", "levo" desno" and "stoj". Because the robot was created in Macedonia, and understood only the Macedonian language, we may say that the first in the world robot whose movement was controlled by speech commands was a Macedonian. It is a possibly a strange sentence but in a sense it is true.

The second worldwide pioneering result is the first control of a robot using signals emanating from a human brain. It happened in 1988 [34] and it solved the long lasting problem, the engineering solution of the science fiction belief in psychokinesis, movement of a physical object using only energy emanating from a human brain.

The knowledge used to approach this scientific challenge was partly influenced from automata theory initiated by Dr. Čupona, the mathematical methods in biology influenced by inspiration from Dr. Čupona and Professor Lozinski in 1968, and EEG knowledge obtained in collaboration between MINC and Neuropsychiatric clinic, mentioned before.

Figure 4 shows the abstract automata graph (Moore type) used in the 1988 design of control of robot using EEG signals.

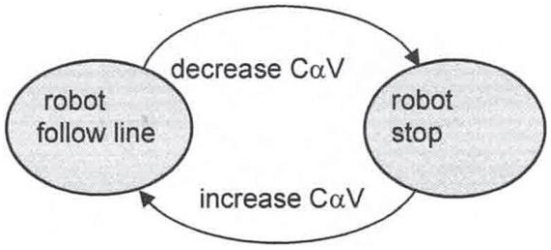

Figure 4. Abstract automaton (Moore type) used in design of the pioneering control of robot movement using EEG signals

As Figure 4 shows, initial (default) robot behavior is following a line on the floor using own artificial intelligence. If a human increases his alpha rhythm amplitude (Contingent alpha variation (CαV)) the robot stops. If CαV is decreased the robot continues its default behavior.

It should be noted that the next result of controlling a robot using EEG signals was reported in USA [35], 11 years after the Macedonian result.

This 1988 event is currently recognized as a historic event in science related to bioelectric sig-

nals. The Royal Society created a timeline chart placing this event as historical achievement [36]. Figure 5 shows part of that history chart.

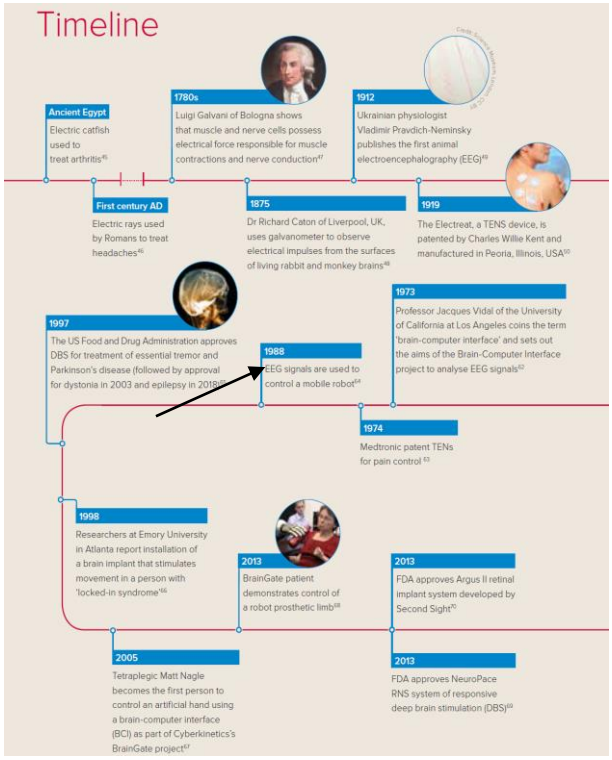

Figure 5. A Royal Society history chart starting from ancient Egypt, pointing out the 1988 historic event

The chart shown in Figure 5 has another page, to the right, not shown here. Note that the chart on Figure 5 should be read left-to-right and then right-to-left. It should be noted that the Royal Society is the oldest scientific academy in continuous existence, and in 1687 they published Newton's Philosophiae Naturalis Principia Mathematica.

1986–1998: ČUPONA AND HIS CARE FOR THE PEOPLE WORKING ON COMPUTER SCIENCE IN THE INSTITUTE OF MATHEMATICS AND INFORMATICS

Institute of Mathematics and Informatics continued the work of MINC. It was a part of Department of Natural Sciences and Mathematics. Dr. Čupona took care of the people employed in this institution. He asked the author of this text to be a Mentor of the PhD Thesis of G. Jovančevski. That way the collaboration continued with Institute of Mathematics and Informatics.

This collaboration produced a work on using a neural network in tuning an operating system [37]. Also it produced a work related to graphical representation of neural network learning in the teaching space and viewing neural network teaching as an integer programming problem. This part of research was carried out with help of Professor Dimitra Karčicka [38, 39]. All this work and collaboration was initiated by Dr. Čupona.

1994–1998: INFLUENCE OF ČUPONA ON MATHEMATICAL EDUCATION OF STUDENTS OF COMPUTER SCIENCE IN MACEDONIA

This author was inspired by the work of Dr. Čupona and his work on algebraic structures [25]. Figure 6 shows cover page of Čupona's book on algebraic structures.

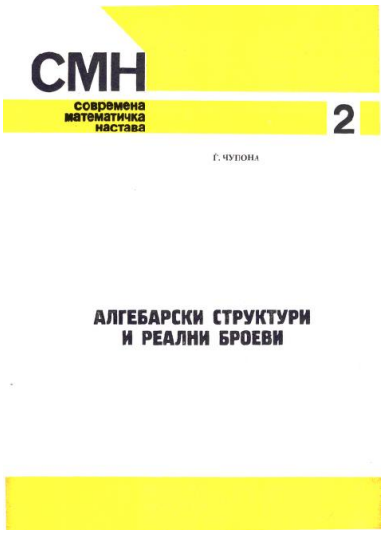

Figure 6. The cover of the 1976 Čupona's book on algebraic structures

Here we list the chapters of the book:

1. Elements of set theory
2. Grupoids. Operations with natural numbers
3. Integers
4. Congruences and isomorphisms. Rational numbers
5. Ordered fields. Real numbers

Influenced by the work on Dr. Čupona on algebraic structures the author of this text provided to his students of Computer Science at the Electrical Engineering Faculty some background on algebraic structures. Two of his textbooks explicitly contained a mathematical Appendix covering the topic.

One of the books was entitled "Operating Systems and Systems Software I: Von-Neumann Computers and Monoprocessing Operating Systems" [40]. The cover page is given in Figure 7.

Figure 7. A 1994 Computer Science book having an Appendix covering algebraic structures influenced by the work of Dr. Čupona.

Here is the list of chapters of the mathematical appendix of this book:

Mathematical basis of operating system DOS and UNIX

1. Files
11. Congregations, collections, sets, populations
1.2. Orderings
1.3. Tree-like orderings. rt strings
1.4. Files, file bases, file spaces, file addresses. Complete file names
2. Commands
2.1. Functions. Compositions
2.2. File functions
2.3 Assumed domains and codomains
2.4. Composition of file functions
2,4, Reporting functions
2.5. Commands
3. Operating systems DOS/UNIX
3.1. File spaces of DOS/UNIX
3.2. Commands of DOS/UNIX

It can be seen that this appendix not only gives background of algebraic structures, but it also uses them to model file structures. In addition, this Appendix has a view that mathematics should start with a concept of congregations (in the book the author used the Macedonian word "zbirstina") because a set has certain rules of formation.

The second Computer Science book containing an algebraic structure Appendix was the book entitled "Robotics and Intelligent Manufacturing Systems" [41]. Its mathematical Appendix contains the following chapters:

1. Non-structured: congregations, collections, sets, populations
2. Primitive structure. Full (Cartesian) product
3. Relations and graphs.
3.1. Transitive relations and their taxonomy
4. From structures to algebras
4.1 Partially ordered sets
4.1.1 Graphical representations
5. Supremum and infimum
6. Lattice structures
7. Algebraic structures
8. Boolean algebras

2005: LAST MEETING WITH PROFESSOR ČUPONA

After 2001 this author joined the Mathematics and Computer Science Department of South Carolina State University. The meetings with Dr. Čupona become rare. The last one was at the funeral of Professor Branko Trpenovski in May 2005. It was just a short, cordial communication, in presence of other people. There was no time for mountain hiking.

2014–2017: ČUPONA'S INFLUENCE IN A MATHEMATICAL THINKING: FROM HIGH SCHOOL COMPETITIONS TO TURING MACHINES AND INFINITE SERIES OF INTEGERS

Here we will mention a mathematical reasoning influenced by the high school competition, mentioned at the beginning chapter of this paper. The reasoning starts with the mathematical term we used very much in mathematics competitions, a^2-b^2. If we consider integers, then for two consecutive integers a = n+1, b = n, where n is even, we obtain the result $n + (n+1) = - n^2 + (n+1)^2$ [42]. For example $0+1 = -0^2+1^2$, $2+3 = -2^2 + 3^2$, etc. Summing those equations step by step to infinity we have

$$1+2+3+4+5+... = 1^2-2^2+3^2-4^2+5^2 - ... \quad (1)$$

The left side of equation is known as Euler-Riemann zeta function for argument -1, ζ(-1), and the right side is Dirichlet eta function for argument -2, η(-2). The equation (1) can graphically be illustrated as in Figure 8.

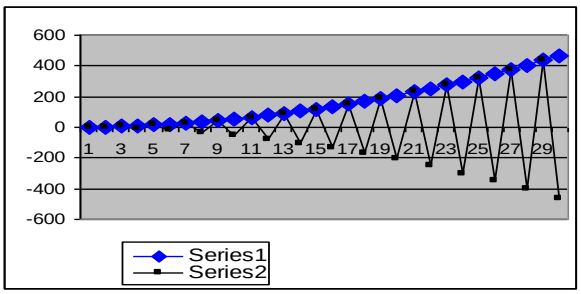

Figure 8. The relation between ζ(-1) (Series1) and η(-2) (Series2)

It can be seen from Figure 8 that the function ζ(-1) is the above envelope of the oscillating function η(-2). That can be described for example by

$$\eta_n(-2) = \zeta_n(-1)\cos(n-1)\pi \qquad (2)$$

where n denotes the n-th partial sum and n goes to infinity. In a Computer Science paper published on this subject [43] equation (1) is related to integers, Turing machines, and infinity.

This work shows the influence and legacy of Dr. Čupona through mathematical competitions, automata and Turing machines, algebraic structures, and integers, which lasts till recent days.

DISCUSSION

This paper takes a historical review, pointing time periods of the development of Computer Science in Macedonia, where Professor Čupona has an essential role. The paper shows the competitive work done in Macedonia in the field of Computer Science and relates it to the worldwide results. Professor Čupona significantly contributed to this cultural competition.

Following the vision of Dr. Čupona, Macedonian Computer Science was able to produce several pioneering results. Here mentioned is the first work on transfer learning in neural networks (1976) in which case the second such work was carried out 15 years later, in 1991, in USA. It is pointed out that this result was achieved by Mathematical Institute with Numeric Center (MINC) which was a creation of Dr. Čupona. Another work mentioned here is the first control of a robot using EEG signals in 1988, in which case the second such work was carried out 11 years later, in 1999, in USA.

CONCLUSION

Professor Čupona made a very significant impact of the development of Computer Science in Macedonia at several levels:

1) As visionary, he has seen that Computer Science should follow the way of algorithms, abstract automata, Turing machines, and related topics.

2) As organizer of Computer Science infrastructure, he formed the Mathematical Institute with Numeric Center in 1966.

3) He was active in working with high school students and mathematical competitions.

4) He was significant supporter of the Institute of Mathematics and Informatics.

5) He created conditions that allowed production of worldwide pioneering results, for example the 1976 result produced by MINC on transfer learning in neural networks.

6) He took care of development of computer science oriented people at Institute of Mathematics and Informatics.

7) He provided educational background on algebraic structures which was followed by many mathematicians as well as computer scientists.

8) He inspired many of his followers to think in terms of algebraic structures, and related topics.

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ПРОФЕСОРОТ ЧУПОНА И РАЗВОЈОТ НА КОМПЈУТЕРСКИТЕ НАУКИ ВО МАКЕДОНИЈА

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Оваа статија дава преглед на придонесот на професор Чупона во развојот на компјутерските науки во Македонија. Пристапот е од гледна точка на историскиот развој, со распон на години наведени за поединпридонес. Се почнува од 1960-тите години и формирањето на Математичкиот институт со нумерички центар. Потоа се истакнува улогата на Чупона во поттикнувањето на првиот труд напишан на македонски јазик од областа на компјутерските науки. Се наведува неговата улога во пионерските достигнувања на македонската компјутерска наука во светот. Исто така, се наведува неговиот придонес како инспирација за користење на математиката во работата и истражувањето во компјутерските науки.

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