Original http://www.icfcst.kiev.ua/MUSEUM/TXT/YuriYushchenko.pdf

Pointers in programs on the computer MESM

For the European Virtual Computer Museum of the History of Information Technologies in Ukraine

Yuriy Yushchenko
Candidate of Physical and Mathematical Sciences

Prelude

The architecture of MESM (Small Electronic Calculating Machine) had unique features that influenced the architecture of computers developed in the USSR [2, 8]. On MESM calculations of the most important national economic tasks were carried out, problems in the defense and space fields were solved. During the programming of these tasks, the important experience was gained, which was successfully used in obtaining outstanding scientific achievements.

Features of the command system MESM allowed the use of unique techniques in programming, which had a great impact on the design and development of high-level programming with powerful capabilities, namely: indirect addressing of higher ranks (e.g. *pointers*). The most outstanding achievement of Ukrainian scientists is in the hardware implementation of "stroke-operation" (dereferencing of pointers) in the architecture of the computer "Kyiv" and the invention of indirect addressing of higher ranks (pointers) in one of the first high-level programming languages – the Address Programming Language (1955).

The experience gained by programmers working on the unique architecture of the MESM computer contributed to the early development of Soviet programming and influenced foreign programming technologies. It is a mistake to think that pointers were invented by Harold Lawson in 1964 for the PL/1 language [1].

Long before commissioning, it was planned to use MESM by a laboratory of calculations at the Institute of Mathematics of the Academy of Sciences of the Ukrainian SSR. This laboratory was created in 1950 by the director of the institute, academician O.Yu. Ishlinsky for calculations related to the solution of navigation problems with using the theory of gyroscopic systems [10]. The head of this laboratory was appointed by K.L. Rvachova (after marriage – Yushchenko). At first, mathematicians defined a sequence of actions for carrying out calculations. Other mathematicians made calculations using logarithmic rulers and electronics arithmometers [10].

In 1951, the mathematicians of the laboratory, who had already received access to state secrets, were provided with documentation on the architecture of MESM, and from 12.01.1952 the laboratory staff was seconded in Theophania and began debugging programs on MESM.

Until 1954, the laboratory of computer engineering that used MESM was located in the Institute of Electrical Engineering (later Electrodynamics) of the Academy of Sciences of the Ukrainian SSR [9, 10]. The engineers of the laboratory were responsible for the operations of MESM, which, in addition to the computing laboratory of the Mathematical Institute of the Academy of Sciences of the Ukrainian SSR, was used by Moscow mathematicians.

The development of each program was seen as a solution to a problem. Mathematicians were looking for ways to write small programs, skillfully using the features of machine commands. Mathematicians tried to generalize programs as much as possible to expand the scope of their use.

Uniqueness of architecture of MESM

The architecture of MESM had three unique features [8, 9], which were absent from other computers at that time:

a) parallel arithmetic processor (to accelerate arithmetic operations);

b) centralized and local control (for writing and using libraries);

c) the possibility of dynamic modernization of the program.

The parallel arithmetic processor was generalized and improved by C.O. Lebedev using the so-called "water supply" approach, which allowed follow-up computers to have higher performance. Also, parallelism was one of the features of the Address Programming Language.

Centralized and local control of program execution was intended for the convenience of programmers when using subroutines.

The limited internal memory MESM (200 cells of plug-based RAM) and the low performance (100 operations/sec), the instability caused by many vacuum tubes (6 thousand), forced mathematicians to use exquisite programming techniques [9]. The execution of one problem was carried out by more than one and sometimes much more) stage. Some stages of execution were performed by mathematicians by traditional means without the use of MESM.

Libraries and subroutines were developed to calculate logarithmic, trigonometric, and other elementary functions. Subroutine libraries were supplemented with subroutines for solving problems in computational mathematics. The presence of centralized and local implementation of programs on the MESM had no like analogues in the world.

In the architecture of the computer "Kyiv" this approach was generalized and improved by determining the unconditional transition not to a specific address, but to an address that was determined by the address of the 2nd rank (a pointer). The address of the command, which was to be executed after the completion of the subroutine, was placed in a special "return" register of "Kyiv" [3, 4, page: 12 in 5]. When using the shifted-soldered RAM extensions, it was not necessary to make any changes in the subroutines of the libraries. Usage of addresses of 2nd rank allowed to return control to the main program without making changes to the subroutines.

Thus, the central and local control of program execution pushed to create interchangeable-soldered blocks with subroutines and constants, which made it possible to reduce the number of vacuum tubes and, by replacing them with a "chip", to increase the amount of cheap RAM of the computer [3, 4, p.: 5-8 in 5].

The dynamic modification of programs together with the technology of control transfer between central and local controllers has led to the possibility in the Address programming language to define subroutine call operator - "***П***" [3, 4, pages: 41, 42 in 5, 6, 7, pages: 23-25 in 11].

The possibility of dynamic modification of programs was of particular importance for the birth of high-level programming and became the starting point for the invention of indirect addressing of higher ranks (pointers).

The possibility of dynamic modification of programs was provided by the so-called “command of addition of commands” (CAC) [8, 9]. A simple use of this command was to sequentially access the elements of the array, and ordinary memory cells were used as index registers, which were not in the MESM. Programming on MESM involved indirect addressing of the 2nd rank (pointers), both for addressing data and for addressing subroutines. In particular, indirect addressing of data allowed to place input data (parameters) for subroutines in arbitrary cells of RAM without changing the code of the program itself. And pointers to the subroutines allowed commands to call an arbitrary program without changing it, the address of which was at the address specified in the command. This approach has made it possible to increase generality of programs.

In the summer of 1952, the Moscow mathematician O.A. Lyapunov came to Theophania to explore the possibilities of programming on MESM. Also, from Moscow came M.R. Shura-Bura and Yu.D. Shmyglevsky, which, together with K.L. Yushchenko and her husband O.A. Yushchenko, solved the problem of external ballistics. As a result of the study of programming on MESM O.A. Lyapunov developed a mathematical formalism – a method of operator programming. Operator programming included capabilities of the MESM command system: conditional transitions (branching), arithmetic operations, and much more. One of the features of operator programming was the introduction of the concept of array. It was the capabilities of the CAC MESM that provided the possibility of sequential access to the values of the elements of arrays. The command of adding commands to sequentially process the elements of the array added the number “1” to the address of the operand of the commands, which is in the body of the loop. Thus, each time the next execution of the commands used the next cell. At the same time, CAC used RAM cells as registers of modify of addresses[1].

The ability of CAC to modify the program was suggested the idea of creating programmable programs, i.e., programs that, changing the contents of the computer memory will create a program in machine codes.

The uniqueness of CAC was used in solving the problem of optimizing the laying of a high-voltage power transmission lines [9, 10]. The program for determining the optimal solution for laying long-distance power lines at the entrance received several parameters on the cost of mounting high-voltage poles of different heights, the cost of their installation, depending on the characteristics of

---

[1] Registers of modernization addresses of the computer "Kiev" have a wider purpose than the well-known Index Registers.

the landscape. It was necessary to obtain the results of calculations by the program with different sequences of input parameter values. Data for programs was entered into the computer's memory separately from the programs themselves, and the programs specified the addresses of the cells in which the addresses with the data are located. To run a program with different combinations of input data the cells containing addresses pointing to the data had to be changed , but nothing more.

This approach made it possible to create programs that, without any changes, had the ability to obtain input values in arbitrary memory cells that can be determined by the programmer immediately before starting the program. That is, the programs have become independent of the location of the original data.

Thus, the first programs using the powerful capabilities of indirect addressing of the 2nd rank (pointers) were created.

The solution of problems in MESM had the status of a state secret, which made it impossible to publish any materials related to programming. In this regard, programming technologies on MESM were not known to other specialists.

Using program cyclic fragment templates

All programs that were written and executed in MESM contained cycles. To speed up the assembly of programs with cycles, so-called loop templates have been developed.

Programmers, when writing a program in mnemonic codes, had the opportunity to specify one of the cyclic fragment patterns, and encoders were able to convert them into binary codes of programs.

Cycle templates began to be used in program mnemonic codes similarly to cycle headers.

The experience of using cyclic patterns significantly influenced the further development of programming. In particular, the command system of the "Kyiv" computer included group operations of modification of addresses of the 2nd rank [3, 4, p.: 53-67 in 5], and in the Address Programming Language the patterns of cycles were generalized and developed in the cycling formulas – ***"C"*** [3, 4, p.: 43-45 in 5, 6, 7, 11].

Use of MESM

In 1952/1953. The following tasks were solved on MESM (the quote from the memoirs of K.L. Yushchenko):

"- compilation of tables for statistical acceptance control (statement of the problem by B.V. Gnedenko, executor K.L. Yushchenko);

- dynamic problems of the theory of elasticity (statement by O.Yu. Ishlinsky, Institute of Mathematics of the Academy of Sciences of the Ukrainian SSR, performer O.A. Yushchenko);

- selection of optimal parameters of mine ropes (production by G.I. Savin and O.Yu. Ishlinsky, performer O.A. Yushchenko);

- *determination of areas of stability of electric power systems, in particular, Kuibyshev HPP (production by L.V. Tsukernik, Institute of Electrical Engineering of the Academy of Sciences of the Ukrainian SSR, performers B.C. Korolyuk, K.L. Yushchenko);*
- *calculation of thermal stresses of building structures (production by A.D. Kovalenko, Institute of Mechanics of the Academy of Sciences of the Ukrainian SSR, performer K.L. Yushchenko);*
- *processing of geodetic observations (production by N.I. Yakubetskaya, performer K.L. Yushchenko);*
- *calculation of ammonia synthesis problems (executor L.N. Ivanenko);*
- *estimation of volumes of earthworks at design of roads (production by A.K. Khavkin, Kyiv Road Institute, executors K.L. Yushchenko, L.M. Ivanenko, A.M. Sibirko)."*

The tasks that were solved on MESM also included the following tasks [9, 10**Ошибка! Источник ссылки не найден.**]:

- optimization of the passage main high-voltage power lines, in particular: Kuibyshev HPP - Moscow (Gnedenko B.V., Yushchenko K.L.) - 1952;
- external ballistics, set by M.V. Keldysh, Yu.O. Mitropolsky and his student Yushchenko O.A. took part in the development of solution methods, and the calculation programs were made by Yushchenko K.L. in cooperation with well-known Moscow scientists and programmers M.R. Shura-Bura, Y.D. Shmyglevsky;
- nonlinear mechanics (Yu.O. Mitropolsky, performer Yushchenko O.A. programming Yushchenko K.L.);
- calculation of thermal stresses of building structures (production by A.D. Kovalenko, Institute of Mechanics of the Academy of Sciences of the Ukrainian SSR, programming by K.L. Yushchenko).

In MESM, K.L. Yushchenko developed an experimental programming program that consists of simple arithmetic expressions of programs in machine codes that calculate their value. During the development of this program, experience was gained, which was used in the implementation of the Address Programming Language compilers.

Summary

While solving these problems, the defense industry, the space industry and the national economy gained experience in the application of exquisite programming methods, in particular the use of pointers (indirect addressing). These methods played an important role in the design of command systems of the asynchronous computer of a wide purpose "Kyiv" and were embodied in one of the very first high-level programming languages: The Address Programming Language (1955).

The use of MESM was of great importance for solving the most important problems of the national economy, defense and space industry of the USSR, and the unique architecture influenced the architecture of other computers, contributed to the emergence of high-level programming and the invention of the most powerful means of all modern programming technologies – indirectly the high-ranks addressing (pointers). Pointers made it possible to introduce tree-like formats into programming, which are like the abstract data types that appeared in programming later.

Literature

1. Alvaro Videla, (Dec 8, 2018), Kateryna L. Yushchenko — Inventor of Pointers. A Computer of One's Own – Pioneers of the Computing Age – https://medium.com/a-computer-of-ones-own/kateryna-l-yushchenko-inventor-of-pointers-6f2796fa1798?fbclid=IwAR3fcqmC0COfy5EqyIHBrlQhCpno5MUFZjCUQ-SM-v-xhD0g3xbj_P2SRCM (accessed: 02.09.2021).
2. Dashevsky L.N., Shkabara K.A., How it began: Memories of the creation of the first domestic electronic computer MESM / Dashevsky L.N., Shkabara K.A. - M.: 1981. — 64 p. (New in life, science, technology. Ser. Mathematics, cybernetics; No 1)– http://www.icfcst.kiev.ua/MUSEUM/DIFFERENT/DSbook_u.html (in Ukrainian, in Russian)
3. Eléments de programmation sur ordinateurs : Par B.V. Gnedenko, V.S. Koroliouk, E.L. Iouchtchenko, Dunod, 362 pages., ASIN: B0014UQTU0. – https://files.infoua.net/yushchenko/Elements-de-programmation-sur-ordinateurs_BGnedenko-VKoroliouk-EIouchtchenko_1969_France_OCR.pdf (in French) (accessed: 19.09.2021).
4. Glushkov V.M. The Kiev Computer; a Mathematical Description / V.M. Glushkov, E.L. Yushchenko // Translation Division, Foreign Technology Div., Wright-Pattenon AFB, USA, Ohio, Mar 1966 – 234p. – 1966, ASIN: B0007G3QGC, en.
5. Glushkov V.M., Computer "Kyiv". Mathematical description / V.M. Glushkov, K.L. Yushchenko. K. : – Gostekhizdat Of the UssR, 1962. – 183 p.: il., ru.,– https://files.infoua.net/yushchenko/Vychislitelnaya-mashyna-Kiev_VHlushkov_EYushchenko_1962.pdf (in Russian) (accessed: 19.09.2021).
6. Gnedenko - Koroljuk - Justschenko: Elemente der Programmierung - Verlag: Leipzig B.G. Teubner, 1964, 327 oldal.
7. Gnedenko B.V., Elements of programming / Gnedenko B.V., Korolyuk V.S., Yushchenko E.L.; M.: – GIFML, 1961. – 348 p., – https://files.infoua.net/yushchenko/Elementy-programmirovaniya_BGnedenko-VKoroljuk-EYushchenko_1961.pdf (in Russian) (accessed: 19.09.2021).
8. Lebedev S.O., Dashevsky L.N., Shkabara K.A., Small electronic counting machine. — M.: Iz-vo AN SSSR, 1952. — 162 p.
9. Malinovsky B.N., History of Computer Engineering in Persons. – Kyiv: "KIT", PTEO "A.S.K.". – 1995; 306 p.– http://elib.ict.nsc.ru/jspui/bitstream/ICT/545/1/Malinovskiy.pdf (in Russian) (accessed 19.09.2021), http://www.icfcst.kiev.ua/MUSEUM/TXT/Malinovsky_history_ukr.pdf (in Ukrainian, in Russian) (accessed 19.09.2021).
10. N.M. Mishchenko, Institute of Cybernetics of the National Academy of Science of Ukraine: it all started in Feofaniya... (1956–1958): memoirs. Part 1 [Electronic resource] / Nadiya Mishchenko // Cybernetics, computer science and around...: scientific works, messages, memories. – http://www.icfcst.kiev.ua/MUSEUM/TXT/m1956-1958-4_u.pdf (in Ukrainian) – (accessed: 19.09.2021), https://cyberua.info/novyny/ik-nanu-vse-pochynalosja-u-feofaniji-spohady-ch1-nadija-mishchenko/ (in Ukrainian) – (accessed: 19.09.2021).
11. Yushchenko K.L., Address programming, K.: – Gos. Publishing House of Technical Literature, URSR, 1963. – 287 p., – https://files.infoua.net/yushchenko/Adresnoe-programmirovanie_EYushchenko_1963.pdf (in Russian) (accessed: 19.09.2021).

Original http://www.icfcst.kiev.ua/MUSEUM/TXT/YuriYushchenko.pdf