Symbolic Computation in 1974∼1976 in Japan

Tateaki Sasaki, Professor Emeritus
Dept. of Mathematics, Univ. of Tsukuba
Tsukuba-shi, Ibaraki 305-8571, Japan
sasaki@math.tsukuba.ac.jp

Abstract

First, this article surveys the beginning of symbolic computation in Japan which had been led by Prof. Eiich Goto with his paper "Monocopy and Associative Algorithms in an Extended Lisp" named HLISP (for Hash-LISP) written in 1974 (*we can get it from Web*) and the first application of the HLISP to the computation of so-called "Feynman graphs in the QED (= Quantum Electro-Dynamics)" by the speaker in 1975. Reading the Goto's paper, the readers will understand that the HLISP saves the memory as much as possible by avoiding the appearance of duplicated lists by hashing, and they will also think that Prof. Goto was stingy. However, if the readers know that the computer we had used at that time for "large computations" was very restricted in the memory (about 1 Mega-words memory), they will understand why Goto deviced to save the memory severly. In addition, we survey very briefly how the computer algebra had been popularized in 1980's in Japan.

Secondly, this article introduces that Prof. Goto is an unbelievably excellent and fantastic **inventor** (he often called himself not a researcher but an inventor). One influential example is a new electron-beam method to evolve the LSI (Large Scale Integrated-circuit) to the VLSI (V means Very), invented in 1975. The speaker will introduces several of such hardware invented by Goto, as well as a Lisp machine.

1 RIKEN (Inst. Phys. Chem. Res.) and Prof. Goto

RIKEN is the most famous national research institute in Japan; two earliest Japanese Nobel-prize winners, H. Yukawa and S. Tomonaga, studied many years at RIKEN. The RIKEN is composed of about 40 laboratories studying physics, chemistry, biology and technology. Many of the laboratory chiefs are also the professors of famous universities of Japan, and Prof. Goto was a professor of Dept. Inform. Sci. of Univ. of Tokyo.

Prof. Goto became famous in 1958, when he was a graduate student of Univ. of Tokyo, Dept. of Physics, by the invention of "parametron". For the principle of parametron, see paper[1] in ref.[1]. At that time, the electronic computers were made of vacuum tubes. The oldest electronic computer ENIAC was made of many vacuum tubes. The parametron has a similar property as the vacuum tube and much stabler. So, many parametron computers were constructed in Japan. About 10 years later, the parametrons were replaced by much faster transistors (semi-conductor device). The transistor itself was discovered in 1948 at Bell Laboratory, however its application to the computer needed many years.

Why Prof. Goto had devised the HLISP? I think that he had met Prof. Anthony Hearn of Univ. of Uta, and had decided to do the symbolic computation of the particle physics, which necessitated him a LISP processor. He pushed me to write an arbitrary precision real arithmetic package in REDUCE (1979). Furthermore, he designed a Lisp Machine named FLATS in 1982 (see paper[5] of ref.[1]), and constructed it in 1984 (we show its picture).

It should be emphasized that the name "Parametron" appeared again in 1986, dressed with clothes "quantum", 5 years before Prof. Goto's retirement. A RIKEN researcher Hiroshi Ohta (my best friend in RIKEN) tried to make a stable Josephson-junction many years. Finally, he succeeded in making a very stable junction. Now, Ohta's device is used as an indispensable one in astronomical observatories. The "quantum Parametron" of Prof. Goto must be affected by Ohta's quantum device. I cannot understand what is the relation between Josephson-junction and parametron. Anyway, the quantum-parametron is studied actively even now.

Contrary to Prof. Goto, I had nothing to proud of myself, except for the academic career: I got the Ph.D on Sep. 1st, 1973 at Dept. of Physics, Univ. of Tokyo, by a thesis on a study of high energy reactions of elementary particles. One day, one member of my thesis screening comm. told me. "Visit Prof. Goto in his room; he is planning to begin a new particle physics using computers; Good Luck!!" (My position at that time was a part-time lecturer of the Dept. of Engineering of a national University.) Prof. Goto suggested me to apply for a one-year post-Doctoral fellow of the RIKEN; the fellow can get a research fund and a salary. The fellow status will be prolonged if he would attain a remarkable research result. Then, Prof. Goto showed me various posters explaining a new style of researches on physics by using computers, such as computing the orbit of a star by power-series expansions. And, he said that, for new computations, we are necessary to use new computer language named "LISP". And, he handed me a copy of "Lisp 1.5" which is a manual of the LISP. Reading the manual at home, I was fascinated very much in the "list" data-structure. This fascination made me to change the research domain from the particle physics to "computational physics".

2 Generation of Feynman Graphs in QED

My application for the post-Doctoral fellow was approved about 5 months before April 1st when the academic years begin in Japan, and I was allowed to use the main computer of RIKEN.

Prof. Goto allowed me to perform any research freely, and I set the first theme to the generation of Feynman graphs. An early version of HLISP processor had been developed by two graduate students, Y. Kanada and M. Terashima. Let me explain the Feynman graph briefly.

By t we denote the **time**. It is conventional to consider that the reactions of particles occur only in the time interval $-t_0 \leq t \leq t_0 \neq 0$. We say that all particles at $t < -t_0$ are in $\boxed{\text{initial state}}$ and those at $t > t_0$ are in $\boxed{\text{final state}}$. In the QED, only three particles are treated: the **electron** having mass m and charge $-e < 0$, the **positron** (= anti-electron) having mass m and charge e, and the **photon** having no mass and no charge; the photon is nothing but the quantum of **light**. The reactions among them are only the following three: **React1**: [**el**] + [**ph**] $\longleftrightarrow$ [**el**], **React2**: [**ps**] + [**ph**] $\longleftrightarrow$ [**ps**], **React3**: [**el**] + [**ps**] $\longleftrightarrow$ [**ph**]. Here, [**el**], [**ps**], [**ph**] denote the electron, the positron and the photon, respectively. The $[A] \longleftrightarrow [B]$ means both $[A] \to [B]$ and $[A] \leftarrow [B]$. Note that both $[A]$ and $[B]$ may be a set of two particles. The point where each reaction occurs is called the **vertex**. The electron and the positron are expressed by **directed solid lines** and the photon is expressed by a **Non-directed dotted line**. The direction shows the charge flow; the direction sign is attached at the line head.

Actually, many reactions will occur almost simultaneously as a unified event, so the graph which represents all the unified reactions is pretty complicated, which is a **Feynman graph**. By $\underline{N_{\mathrm{od}}}$ we denote the **order** (= the number of whole vertices) of a graph, and by $\underline{n_{\mathrm{a}}}$ and

n'_{a} we denote the numbers of particle [a] in the initial and the final states, respectively, where $\mathrm{a} \in \{[\mathbf{el}], [\mathbf{po}], [\mathbf{ph}]\}$. By "generating Feynman graphs" we mean that, by setting N_{od} and n_{el}, n_{po}, n_{ph}, and n'_{el}, n'_{po}, n'_{ph}, generate ALL the graphs satisfying the given 7 numbers, with NO duplication. The algorithm consists of graph-formation step and same-graph removal step. As for the first-step, readers will admire (in)equalities of pioneers in Subsect. 3.1 of [2]. The second-step was done by human previously, and done automatically in my program.

The paper[2] changed my fate rapidly and largely. At September in 1975, I was employed by RIKEN as a researcher. I was invited by USSR to attend Int'l(Comm-st) conference, where I met Prof. Hearn who was also invited. This led me 10-months staying at Univ. of Utah ⇒ Prof. Goto ordered young Japanese researchers who stayed a year or so in USA "write a research book of about 100 pages" ⇒ I published a book of the title "Formula Manipulation" (1981).

3 [LSI to VLSI] in Japan was Done by Eiichi Goto

[1] When I joined Goto Lab. of RIKEN (April in **1975**), Prof. Goto has almost finished developing a high-precision electron-beam method for specifying twinkling points in pictures obtained from collisions of high-energy particles. I wondered why he was interested in such a topic. Soon, I remembered that he was searching for "monopole" (an elementary particle having either N-pole or S-pole only; such a particle has not been found yet). The constructed instrument was settled at National Laboratory on High Energy Physics (⇒ best place for monopole searching).

Just at that time, it was said that IBM (later, we knew Tomson in France, Bell Laboratory in USA, too) would develop a new series of computers. This was a matter of life-and-death for Japanese computer makers. The most modern computers at that time was based on the LSI manufactured by exposing patterns with ultra-violet light. Thus, it was almost obvious that the next key technology is the VLSI manufacturing by the electron-beam exposure. It was lucky for Prof. Goto that, in the previous research described in the above paragraph, he and his former student Ooiwa have constructed a theory for eliminating the **optical aberration** of electron-beams considerably. Hence, Prof. Goto ordered an old obedient Sohma who had no Ph.D: "Use REDUCE (a formula manipulation system) and perform computations as I tell you". Prof. Goto advanced his thinking through mathematical formulas obtained by REDUCE. Furthermore, he talked to me: "Sasaki kun, we will handle high-current electron-beams. Will you investigate the effect of space-charge (= electron-electron interaction in the beam)?" I answered at once: "Yes Sir, Easy Jobs!". ⇒ RIKEN took out core patents earlist in the world.

At March 10th, **1976**, Ministry of Trade and Industry established the "VLSI Research Co-operative Society", and 26 companies joined to it at once. Most researchers in the Research Cooperative Society have little experience of handling the electron-beams itself. Hence, the Society must be almost a lecture room of Prof. Goto. (Sasaki did not attend any meeting on electron-beams. He attended only meetings on computer algebra that he organized.)

In RIKEN, if the Lab. chief retires then the Lab. disappears ⇒ Lab. members loose their status. At the middle of each March, **Farewell Party** is organized for persons leaving RIKEN. In 1991, two persons were listed from Goto Lab: Goto and Sasaki. All the attendants surprised, because Sasaki (lecturer class) was announced to move to Univ. Tsukuba, as a Professor.

References

[1] T. Ida: In Memoriam Professor Eiichi Goto. ACM SIGSAM Bulletin, **39** (3), 71-72 (2005)

[2] T. Sasaki: Automatic Generation of Feynman Graphs in QED. J. Comp. Phys. **22**, 189-214 (1976).

[1] For details of Goto's work, see (science historian) Shunsi Koyama's paper (in Japanese), J. History of Science, Japan, **46** (243), 155-166, 2007. [DOI] *http://doi.org/10.34336/jhsj.46.243_155*