

## Multibody Systems History of ADAMS

My kinematics and dynamics activities began in 1963 when I was offered a job as assistant (not to be confused with an assistant professor) to teach seminars and laboratory for theory of machinery and mechanisms (TMM) at the Polytechnic Institute of CLUJ Romania.

Based on this activity, it was recommended to me, by one of my professors who visited the U.S., to come and seek a graduate degree in the U.S. After a long wait, I received the exit visa to come to the U.S. I arrived in the U.S. on Feb. 25, 1970. I was well aware and have studied the worldwide activity regarding TMM. However, I did not have computer programming knowledge and spoke very little English. So, I was directed to attend the English Language Institute in Ann Arbor at the University of Michigan.

In the field of TMM, there were sporadic studies for solving the kinematics and dynamics of 3D and multi-degrees-of-freedom mechanisms. There were two distinguished programs: The John Uicker 4X4 matrix formulation that was implemented in the integrated mechanism program (IMP) computer program, and Milton A. Chace formulation for 2D multi-degrees-of-freedom mechanisms implemented in dynamic response of articulated machineries (DRAM) computer program. An organized field of multi-body systems kinematics and dynamics did not exist.

In 1970, after my arrival in the U.S., while studying English at the English Language Institute of the University of Michigan, my good fortune was that I coauthored a dynamics paper for the ASME conference in Columbus, OH [1]. There, I met Professor Milton Chace and Professor John Uicker. Professor Chace asked me what are my future plans. I told him that I wanted to study in a graduate program. He told me that the University of Michigan is a good place, and he promised me that he would help me to stay there. A month later, I got a phone call from Professor Don Calahan, from the Electrical Engineering Department, inviting me for an interview. Soon after that, I was accepted as a graduate student having two advisors. Professor Milton Chace from the Mechanical Engineering Department and Professor Don Calahan from the Electrical and Computer Science Department. In our further discussions, Professor Calahan let me know about IBM's simulation program named advanced statistical analysis program (ASTAP) and its simulation tools [2]. One of the tools was sparse matrix methodology. Professor Calahan also told me that he envisioned a program for mechanical system simulations that does not use matrix inversion or matrix multiplications. That is because they require too many computer operations and therefore are expensive and inefficient. He then continued to tell me to avoid multiplying numbers with zero because they required the same computer time as the multiplication of two nonzero numbers, and we know the result before the operations take place. It became clear to me the importance of the numerical efficiency. Based on our discussion, I had chosen for numerical integration of the implicit backward difference formula (BDF) known also as the *Gear algorithm*. My choice was due to the numerical stability of the implicit backward numerical integration methods. It also solves numerically stiff problems. Although one can seldom find numerically stiff mechanical systems. However, they do exist. During my studies at

the University of Michigan, I met Pardip Sheth who finished his Ph.D. under the supervision of Professor Uicker. Pardip and I discussed a lot of problems and research of common interest. I also attended a graduate class in linear dynamics that Sheth taught.

During this time, John Uicker, with IMP, and I, with my computer program that was in progress, had participated in a project launched by SAE's strain evaluation committee. The benchmark was the numerical dynamic simulation of the front suspension of Chevrolet Malibu. The data and the experimental work were done by GM Chevrolet Engineering Division located in Warren, MI. We submitted the results to the SAE committee. Both simulations, independently done, were agreeable and quite close to the experimental data. This was a good news.

I graduated with a Ph.D. in 1973. My thesis was formulated by a nodal formulation, sparse matrix techniques named sparse tableaux formulation (STF), BDF, and Lagrange's equations. All of these were incorporated into the computer program that I designed to numerically simulate multibody 3D systems [3]. I called it automatic dynamic analysis of mechanical systems (ADAMS).

In 1974, I was simulating the landing gear of a Boeing 747, a full car, and the distorted lattice of graphite called glassy carbon used for lining the inside of nuclear reactors. All of this using the ADAMS computer program. These were machines, mechanisms, and material lattices. This was more than mechanisms and machines. I called it "Multibody System Dynamics." This definition was readily accepted also by the European scientific community.

Shortly after that I was out of the country for a short period of time. I returned to the U.S. via Dublin, Ireland with the help of Professor Milt Chace. By then, Mechanical Dynamics, Inc. (MDI) introduced ADAMS as one of their products. I was very pleased that MDI assumed the responsibility of disseminating ADAMS around the world. Professor Chace have had always the idea of commercializing ADAMS. This turned out to be an important asset in the life of the program. Because of the users feedback and demands, there is a continuous improvement activity of the program that is supported by MDI and myself.

A free copy of the original ADAMS (not to be confused with the commercial ADAMS) could be obtained until 1984 from Cosmic that is located in Atlanta, GA. However, whoever asked for it, needed to rewrite some parts specific to their computer and their operating system. Originally, ADAMS was written using Michigan Terminal System (MTS) and an Amdahl computer.

I was looking for a job and that was difficult to find because of my visa status combined with the crisis of the oil embargo. In 1974, I was involved with the University of Michigan Medical School as part of a group of five scientists who designed the first gamma ray scintillation camera transaxial tomograph for diagnosing brain tumors. I like to talk about this project because of the human aspect of it. Having now a multibody system, I used it to completely design the machine and supervise its execution. The *Journal of Nuclear Medicine* acknowledged it [4].

Soon thereafter, I was offered a Visiting Associate Professorship at the Iowa State University (ISU) located in Ames, IA. In

consideration of Professor Chace's help with my return to the U.S., I asked him to take care of the ADAMS. From time to time, MDI asked me for help in supporting ADAMS.

In the advanced kinematics class at the ISU, I met Roger Wehage, a graduate student. I recognized good things in him. He listened, he worked hard, and put the things that he learned through his filter. I was impressed and I suggested that he go for his Ph.D.; I am glad he did it. It turned out well.

In 1976, I received an offer for a permanent job at the Deere and Company where I worked for 21 years. I felt bad, however, that I had suggested Roger to go for his Ph.D. and subsequently I left the university. Professor Chace and Professor Calahan presented ADAMS at the ASME conference in Montreal, Canada. As a consequence, I was invited by Professor Edward Haug to teach the theory of ADAMS at University of Iowa in Iowa City, IA. I accepted it, and I was very happy to recommend Roger as a graduate student for Ph.D. Ed accepted Roger as a graduate student and that turned out good for both of them. After the ADAMS class was finished, Ed started a multibody system simulation research at the University of Iowa. Roger and Ed developed the dynamic analysis and design system (DADS) computer program. Later, a lot of good researchers came from the University of Iowa. To name a few: R. Wehage, A. Shabana, and A. Sheffer.

While I was working at the Deere & Co., in my free time, I continued to work at ADAMS by developing "lower index methods of numerical integration" for STF that included ADAMS and the 2D simulation program developed by Roger and me. I called this program mechanical computer-aided dynamic analysis (MCADA). This program is used to test different numerical algorithms. Examples are index one second-order Newmark and HHT numerical integration methods for STF, etc.

After retiring from John Deere (1997), I moved back to Ann Arbor, MI. I worked as an adjunct full professor at the University of Michigan in Mechanical Engineering. MDI purchased an eternal license from me to use STF Index 2 methods. I supported Index 2 and did some debugging for MDI ADAMS until year 2007. At that time, my health began to deteriorate. In 2000, I had a quintuple coronary bypass, and in 2003, I retired from the university. I continued to be an associate editor of the IMechE *Journal of Multibody Dynamics* until 2007 when Professor Ahmed

Shabana took the torch. While teaching at the University of Michigan I got interested in *parallel kinematic structures*, such as *hexapods*. These structures are amazing. They are used for airline pilot training, precision machine tools, precision medical devices, etc. However, one must be paying attention to hexapods use because some types of simulators can be white elephants.

At the University of Michigan in the year 2000, I organized and chaired the "2000 International Conference In PKM." It was a successful endeavor because we had scientists from all over the world.

I would like to conclude by mentioning three very important scientific events in the life of ADAMS that were introduced at different times. The first one is writing the first version of ADAMS. The second is the flexibility introduced by Gisly Ottarson based on Ahmed Shabana's work. The importance of this event is that it opened the door for durability simulations. The last event is the introduction of lower index methods for STF. This addresses the numerical quality of the results. It was proved by Gear [5] that the Index 2 is sufficient for mechanical systems. Index 1 also works well, but is not as efficient as Index 2 due to overhead costs associated with using acceleration constraints.

## References

- [1] Maros, D., and Orlandea, N., 1971, "Contribution to the Determination of the Equations of Motion for Multidegree of Freedom Systems," *ASME J. Eng. Ind.*, **93**(1), pp. 191–195.
- [2] IBM, 1971, "ASTP (Advanced Statistical Analysis Program)," System Products Division, IBM, East Fishkill, NY, pp. 192–195.
- [3] Orlandea, N., 1973, "Node Analogous, Sparsity Oriented Methods for Simulation of Mechanical Dynamic Systems," Doctoral thesis, The University of Michigan, Ann Arbor, MI.
- [4] Keyes, J. W., Jr., Orlandea, N., Helderks, W. J., Leonard, P. F., and Rogers, W. L., 1977, "The Humongotron: A Scintillation Camera Transaxial Tomograph," *Nucl. J. Med.*, **18**(4), pp. 381–387.
- [5] Gear, C. W., 1988, "Differential-Algebraic Equations Index Transformation," *SIAM J. Sci. Stat. Comp.*, **9**(1), pp. 39–47.

**Nicolae V. Orlandea**  
**Deere & Co. Technical Center,**  
**Moline, IL 61265**  
**e-mail: orlanico@umich.edu**