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SOME ASPECTS OF THE EVOLUTION OF COMPUTATIONAL MECHANICS IN ARGENTINA AND THE RÔLE OF EDUARDO DVORKIN

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Abstract. Computational mechanics began in Argentina after the first computer in an Argentinean university was installed for scientific applications at the Instituto de Cálculo, University of Buenos Aires, in 1961. Due to political upheavals in the period 1966-1983 its development was slow - but constant; eventually, the Argentinean Association for Computational Mechanics was created in 1985. That year Eduardo Dvorkin returned to Argentina, and from then on his impact and influence on computational mechanics was significant. We analyze in this contribution some aspects of the evolution of this discipline in Argentina since its beginnings in 1961, its relationship to informatics and applied mathematics and the role Dvorkin played in it during the last 25 years.

1 INTRODUCTION

With the military coup-d'état that overthrew the constitutional President Arturo Illia in 1966 a long period began in which, due to political persecutions and a total incomprehension of the authorities regarding the value of local science and technology, it was extremely difficult to do research and development in Argentina, except in isolated pockets, generally out of the Universities. The period, which included the tumultuous civilian administration of 1973–76, ended in 1983 when, due to a lost war and to the economic crisis, the military had to abandon power; Raúl Alfonsín was inaugurated as President, after winning the elections, on December 10, 1983. Some very consolidated sciences, such as biomedical disciplines and organic chemistry, resisted more or less the general deterioration, but some new areas, with a scarce critical mass, suffered particularly hard. Among these areas are included computational mechanics, informatics and applied mathematics.

As it is defined, for instance, in Wikipedia, computational mechanics "is the discipline concerned with the use of computational methods to study phenomena governed by the principles of mechanics"; it needs mathematics (above all, applied mathematics), computer science and mechanics. From its dependance on computer science it may be inferred that its development in Argentina could not have begun before 1961, when a computer (a Mercury computer sold by Ferranti, a British company based in Manchester) was installed for the first time in an Argentinean university (see Factorovich and Jacovkis (2009)), namely the University of Buenos Aires. In fact, one may affirm that computational mechanics in Argentina was born with the group at the Instituto de Cálculo[1] headed by Mario H. Gradowczyk[2] that worked in continuum mechanics using the Mercury computer and the group of scientists and engineers at the National Agency for Atomic Energy (CNEA) who also used this computer (among them Emma Pérez Ferreira, who many years later was the President of CNEA). Anyway, this activity ended abruptly in 1966 with the already mentioned coup-d'état, and there was only a very weak activity until President Alfonsín was inaugurated in 1983.

"Weak activity" does not mean no activity, however. In spite of the fact that research was not especially backed by the Government during this period, some groups of researchers, often isolated, worked in computational mechanics; thanks to the efforts of Guillermo Marshall, the short-lived Argentinean Association for Applied Mathematics (ASAMA) organized the First Symposium on Numerical Methods in Continuum Mechanics from 18 through 22 July, 1977 at the Goethe Institut, in Buenos Aires[3]. The papers contributed from Argentina (some came from Brazil, Chile, England and Germany) were thereafter published in Marshall (1977) and offer a view of the places where people worked then in computational mechanics: CNEA (Buenos Aires and Bariloche), the Navy Department of Research and Development, National University of Rosario, Southern National University (Bahía Blanca), National University of La Plata, National Institute of Industrial Technology (INTI), University of Buenos Aires, Department of Defense Directorate of Research and Development, National Agency of Spatial Research (CNIE), Estudio Gradowczyk y Asociados, National Council for Research and Technology (CONICET),

[1]The Instituto de Cálculo, where the computer was installed, was a sort of Institute of Applied Mathematics, with a very active and dynamic life since the Mercury began working in 1961 until the military coup-d'état in 1966.

[2]Gradowczyk and his colleagues worked mainly in fluvial hydraulics, especially mathematical models of rivers with a mobile bed.

[3]ASAMA had been created in 1975, but ceased its activities soon after this Symposium. Only in 2008 a new Association for Applied, Computational and Industrial Mathematics was created, with a strong backing from the Argentinean Association of Computational Mechanics (AMCA).

National Technological University, National Agency for Geoheliophysical Studies (CNEGH), National Meteorological Service (SMN), Techint, National Institute for Water Research and Technology.

Activities continued in these agencies, universities and firms, without a particular planning of the government. Thanks to the efforts of some researchers, mainly from Bariloche and Santa Fe, a meeting was organized in 1983 in Bariloche, namely the First National Meeting of Researchers and Users of Finite Element Methods (I ENIEF), followed by the Second and Third Meetings, also in Bariloche, in 1984 and 1985, respectively, and eventually, in 1985, AMCA was founded in Paraná when the First Argentinean Congress of Computational Mechanics (and Sixth Latin American Congress of Numerical Methods in Engineering) took place. We can see a strong bias towards finite elements methods, but the community included also researchers whose main fields were others. Eventually, although in order to maintain the tradition the name ENIEF was conserved, ENIEF meetings became meetings of the computational mechanics community.

Before finishing this section, let us comment on another serious obstacle to research with a technological bias in Argentina, that was a constant in almost all periods of Argentinean history of science and technology: scientists were often extremely diffident of "applied" research, where "applied" meant that the product of their investigation could be eventually commercialized and money could be then obtained: independently of their political ideas, many scientists did not want to "contaminate" their research, in the sense that research should be focused without thinking of immediate applications and benefits. This approach, of course, relatively benefited "pure" research with regard to "applied" research and, above all, to technological research. As is well known, it is often more complicated to evaluate the quality of technological research than the quality of traditional scientific research.

2 DIFFICULTIES AFTER 1983

With the return to democracy in 1983, Manuel Sadosky, an applied mathematician with a long expertise in management of science - he had been Deputy Dean of the School of Sciences during the period 1959–1966 and Head of the Instituto de Cálculo at that School from 1961 through 1966 - was appointed Secretary of State for Science and Technology by President Alfonsín. The scientific and technological policy of the new administration acquired for the first time in many years a background of coherence: scientists and academics who for political reasons had not been appointed professors at the Universities or fellows of the CONICET (or had been fired from their positions for political reasons during the military dictatorships or during Isabel Perón's administration between 1974 and 1976) returned to the Universities and/or to the CONICET - or were for the first time appointed, and a strong support was given to informatics, a discipline which, as we have mentioned, was extremely weak in our country, contrariwise to the international trend. As one of its results, computers began to flow into the research centers; although much less than was necessary (and proportionally much less than, for instance, Brazil), this influx contributed to the development of computational mechanics. Already a critical mass of researchers began to appear, and Santa Fe and Bariloche continued being the main centers of research in our country.

The political arbitrariness was not the only problem affecting research in computational mechanics, however. A cultural obstacle existed, that influenced research in all branches of engineering: tradition of research in engineering was extremely weak all over Argentina. Many members of the engineering community, and many authorities of institutions strongly related to engineering, were interested only in professional applications, and did not realize that for developing Argentinean technology (when possible) a critical mass of engineers specialized in research and development (R&D) should appear, and for this mass to appear research should be stimulated in Universities, Ph. D. programs in engineering should be created in several national universities, and engineers interested in research with Ph. D. degrees obtained abroad should be offered positions at universities. Again, Bariloche and Santa Fe, contrariwise to the general mood, had tradition in research in engineering.

Cultural changes being extremely slow, in general, to be accepted, this was a long process; the School of Engineering at the University of Buenos Aires, for instance, established its Ph. D. program in the eighties, but the first Ph. D. degree was conferred in 1995[4].

3 DVORKIN IN ARGENTINA

Eduardo Dvorkin had obtained his degree of electromechanical engineer, with a major in mechanics, in 1974, at the School of Engineering of the University of Buenos Aires. The possibilities in those times of being admitted at the School of Engineering as a graduate student were nil: not only, as has already been mentioned, a Ph. D. program in engineering did not then exist, but also for political reasons (had that Ph. D. program existed) Dvorkin was a kind of outcast at the University[5]; therefore, he took a position as project engineer at a private company, Establecimientos Industriales Febo, where he worked until he was admitted as a graduate student at M.I.T. in 1980, and where eventually - before going to Boston - he became the Head of the Engineering Department.

After obtaining his Ph. D. degree in Mechanical Engineering at MIT in 1984 under the advice of Klaus-Jürgen Bathe (with a strong specialization in finite element methods), and working at Bathe's company, Adina, as a Research Engineer, Eduardo received a challenging offer: to return to Argentina and take a position as a Researcher in the Development Division of Tenaris-Siderca, a branch of the Techint Organization[6], one of the scarce Argentinean industrial firms which were, in a sense, really international, and one of the scarce Argentinean industrial firms, besides, that decided to create a research and development unit. Let us remember that, as has already been commented in the previous sections, democracy had just been reestablished in Argentina, the culture of research was weak, the culture of technological research was weaker and nobody could assure that, taking into account the history of Argentina from 1930 on, another military coup-d'état was impossible: many scientists and professors did not want to abandon their activities abroad, where they were consulted and respected, had convenient resources, budgets and grants for their work, were surrounded by a high-quality environment and, above all, had stable positions, in the sense that nobody would fire them if they had not the "right" political opinions (that is, their situations were just the opposite of what they were used to in Argentina). Besides, the economy of the country was in shambles after the Argentinean defeat in an absurd war against the United Kingdom.

Those were the "boundary conditions" in Argentina when Dvorkin returned in 1985. Many things have changed in these twenty-five years, and it is interesting to analyze Dvorkin's rôle in the changes.

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[4]Also in computer sciences the process of constituting a critical mass of researchers was slow: the first Ph. D. degree conferred in Argentina was obtained in 1996 at the National University of San Luis.

[5]Not to mention that, from 1974 on, people with suspicious ideas run the risk of physical danger, including death, in places so surveiled by the Police as Universities were.

[6]Techint develops many different activities related with production of steel. In particular, it is the most important producer of seamless steel tubes in the world.

4 THE PAST 25 YEARS

Since his incorporation to Techint, Dvorkin worked in basic research on the finite element method applied to nonlinear continuum mechanics, on numerical modelling of the processes involved in the manufacturing of steel products, and on numerical modelling of steel products service conditions. Eventually he was appointed (in 1995) General Director of the Center for Industrial Research (CINI) of Techint, and held that position until he established his own firm in 2007. CINI was (and is) the most important private research center in Argentina, with over 100 researchers working in it, mainly physicists and engineers, and the usefulness of Dvorkin as member of Techint Organization (that is, the usefulness of his technological and scientific contribution to the success of Techint's business) may be inferred from the generous backing that Techint offered to his participation (as a leading figure) in many international congresses, conferences and workshops devoted to computational mechanics (approached both from the scientific and technological points of view), and the generous economic backing of the scientific meetings organized in Argentina in which Dvorkin participated.

Besides his work in Techint Dvorkin contacted, as soon as he arrived in Argentina in 1985, his alma mater, the School of Engineering of the University of Buenos Aires, and was immediately appointed full professor of solid mechanics at that School. He involved himself enormously not only in teaching and research activities (he was one of the first professors of the new democratic period interested, and with experience, in scientific and technological research) but also in the training of young undergraduate and graduate students and young professionals in modern approaches to mechanical engineering, and contributed significantly to build bridges between university and industry[7]. Besides, he actively participated in the School policy, influencing it as much as possible in order that it adopted more and more a scientific and technological bias, not instead of, but besides, its traditional professionalist rôle. In particular, he was a member of the Council of the School in 1990.

That year, after the School of Engineering more and more abandoned modern orientations in teaching and research, Dvorkin resigned from his position as professor, and during several years decreased his involvement with the School. Eventually, a new administration of the School took up again a scientific and technological focus, and Dvorkin returned again as a full professor (of computational mechanics) in 1997. He also participated again in the Council of the School during several years. Meanwhile, he has advised about scientific and technological policies both the federal government and the Buenos Aires local government in many committees and instances.

It is not the object of this presentation the description of Dvorkin's scientific contributions, although the following may be mentioned:

- The shell element (MITC4) developed by Dvorkin in his Ph. D. dissertation, which is now, by default, the element of all finite element programs. Today MITC methodology for developing finite elements has been adapted by many mathematicians and, in fact, there are special sections on this methodology in many congresses. It is very successful and provides excellent solutions for infinitesimal strain analyzes using either elastic or

[7]Building bridges between universities and industries has been a difficult task all over the world. In Argentina, as in many developing countries, the task is more difficult due to the fact that not only the traditional diffidence of researchers vis-à-vis commercial applications exists, as we have already mentioned, but also because two different ways of thinking converge in a strange merging: the traditional extreme right ideology, for which the capitalist world perturbs the traditional way of life, and the extreme left, for which any action contributing to the economic welfare of private firms is suspicious.

elasto–plastic material models in linear or nonlinear geometrical formulations. In this regard, we may mention particularly three papers, namely Dvorkin and Bathe (1984), Bathe and Dvorkin (1985), Bathe and Dvorkin (1986).

- The method of embedded localization lines, to model problems with localizations, on which we may mention Dvorkin et al (1990); interestingly enough, although this paper was published in 1990, it is currently being more and more known and its influence has significantly grown in the last years. The method is a new finite element formulation aimed at the solution of problems involving strain localization. The formulation incorporates displacement interpolated embedded localization lines. Results are shown to converge to an "exact solution" when the mesh is refined and also to be quite insensitive to mesh distortions.

- The developing of the method of pseudo-concentrations, to model problems of metal forming; although this method was introduced by Erik Thompson (Thompson (1986)), Dvorkin and his collaborators adapted the method in three dimensions, in an industrial scale, and with validated cases. This work originated the software METFOR, and it is a pleasure for me to mention this, because in the last four years I have contributed to its parallelization. Among the published literature on this subject, Berazategui et al (2006) may be for instance mentioned.

Besides, let us comment that Dvorkin has already been visiting professor at the Universitat Politècnica de Catalunya, Stuttgart Universität and Stanford University; has advised 5 Ph. D. thesis, 3 M. S. thesis and around 10 undergraduate thesis; and he is a member of many national and international scientific and technological organizations, including the National Academy of Exact, Physical and Natural Sciences of Buenos Aires.

I want also to stress the deep involvement of Dvorkin in the integration between research and society. Regarding this, one of the finest accomplishments in which he actively participated was the agreement between the National Council for Scientific and Technological Research (CONICET), backbone of the Argentinean scientific and technological system, and Tenaris, member of the Techint Organization, so that researchers who are fellows of CONICET can perform their research in Tenaris; the agreement is not a statement of purposes, it indicates a change of both corporate and scientific mentality, that contributes to the Argentinean development.

5 CONCLUSION

I would like to finish this presentation using words that Dvorkin himself has used in a talk he offered at Stanford some months ago, and which synthesize his ideas about science, technology and their relation:

> There is no single word "science–and–technology," even though we usually use those three words as only one. Science and technology are two different areas, each one with its own goals, its own rules, its own codes of ethics, etc. Technological development is not the necessary objective of valuable scientific research, and also science is not the prerequisite for developing technology. Many times a technological development has been achieved before the proper scientific knowledge has been developed. However, scientific engineering and applied scientific research have been extremely important since the second world war, and many technological developments are rooted in solid scientific knowledge. A society that

can link science and technology without endangering pure scientific research, is a society that will increase the value of its production and will produce high quality jobs for its members.

Dvorkin has been involved in the last 25 years in building links between scientific knowledge and technological development, in his own field, namely computational mechanics, and also, through his active participation in public and private institutions and in the media, in others like nuclear energy, radar, space technology, steel industry, power generation, software: areas already relatively developed or developing in Argentina, but about whom there is a general consensus in the sense that they will be key factors in converting Argentina in a developed society.

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REFERENCES

Bathe, K. J. and Dvorkin, E. N. A four-node plate bending element based on Mindlin / Reissner plate theory and a mixed interpolation. *Int. J. Numerical Methods in Engng.*, 21:367–383, 1985.

Bathe, K.J. and Dvorkin, E.N. A formulation of general shell elements - the use of mixed interpolation of tensorial components. *Int. J. Numerical Methods in Engng.*, 22:697–722, 1986.

Berazategui, D.A., Cavaliere, M.A., Montelatici, L. and Dvorkin, E.N. On the modelling of complex 3D bulk metal forming processes via the pseudo–concentration technique. Application to the simulation of the Mannesmann piercing process. *Int. J. Numerical Methods in Engng.*, 65:1113–1144, 2006.

Dvorkin, E.N. and Bathe, K.J. A continuum mechanics based four-node shell element for general nonlinear analysis. *Engng. Computations*, 1:77–88, 1984.

Dvorkin, E.N., Cuitiño, A.M. and Gioia, G. Finite elements with displacement interpolated embedded localization lines insensitive to mesh size and distortions. *Int. J. Numerical Methods in Engng.*, 30:541–564, 1990.

Factorovich, P. and Jacovkis, P.M. La elección de la primera computadora universitaria en Argentina, in: Jorge Aguirre and Raúl Carnota (eds), *Historia de la informática en Latinoamérica y el Caribe. Investigaciones y testimonios*. Universidad Nacional de Río Cuarto, Río Cuarto, 83–97, 2009.

Marshall, G. (ed) *Métodos numéricos en la mecánica del continuo*. EUDEBA, Buenos Aires, 1977.

Thompson, E. Use of pseudo-concentrations to follow creeping viscous flows during transient analysis. *International Journal for Numerical Methods in Fluids*, 6:749–761, 1986.