Professor John T. Katsikadelis

Professors Carlos A. Brebbia & John T. Katsikadelis

See:
http://users.ntua.gr/jkats/
http://www.researchgate.net/profile/John_Katsikadelis
http://www.wessex.ac.uk/general-news/eulogy-to-john-katsikadelis.html

School of Civil Engineering
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Biography:
Civil engineer J.T. Katsikadelis & Z. Bakalis Incorporated, Athens, 1962-1974; lecturer engineering National Technology University, 1970-1982, professor, since 1982, head department, 1988-1990, 93-95, director Institute Structural Analysis and Aseismic Research, since 1984; Professor structural analysis School Corporation Engineers, Hellenic Army, Athens, since 1976; director general Earthquake Planning and Protection Organization, Greece, 1989-1992, European Center for Prevention and Forecasting of Earthquakes of Council Europe, Athens, 1989-1992; correspondent Council Europe, 1989-1992, European Economic Community, 1990-1992; science committee European Center Nonlinear Dynamics and Aseismic Risks/Moscow, since 1991; expert of European Economic Community in seismic hazard research, 1993. Co-author: The Boundary Element Method for Plates and Shells, 1991; contributor articles on structural dynamics and analysis of plates by the boundary element method to scientific journals; member editorial board international journals.

Degrees:

PhD (Doctor of Philosophy) in Applied Mechanics, Polytechnic University of New York, Brooklyn, N.Y.
Dr. Eng. (Doctor Engineer), National Technical University, Athens, Greece.
MSc (Master of Science) in Applied Mechanics, Polytechnic University of New York, Brooklyn, N.Y.
Diploma Civil Engineer, National Technical University, Athens, Greece.
Mathematical Studies, Department of Mathematics, University of Athens.

Academic Carrier and Positions held:

1970-1982	: Scientific Assistant and Senior Lecturer of Structural Analysis at the School of Civil Engineering, NTUA.
1982-2004	: Assistant, Associate and Full professor of Structural Analysis at the School of Civil Engineering, NTUA.
2004-	: Emeritus Professor, NTUA
1975-2008	: Professor of Structural Analysis at the School of Corps of Engineers of the Hellenic Army.
1988-1990 & 1993-95	: Head of the Structural Engineering Division of NTUA.
1984-2004	: Director of the Institute of Structural Analysis and Aseismic Research of NTUA.
1989-1992	: Director of the Earthquake Planning and Protection Organization of Greece.
1989-1992	: Director of European Center on Prevention and Forecasting of Earthquake (ECPFE) of the Council of Europe.
1989-1992	: Permanent Correspondent of Greece in the Open Partial Agreement (OPA) of the Council of Europe for the "*Protection Against and Relief of Major Natural and Technological Disasters*".
1991-1992	: Representative of Greece in the Permanent Network of National Correspondents for Civil Protection of EU.

As the Director of ECPFE, EPPO, and Permanent Correspondent in OPA he took the initiative and worked for the establishment of the *European Code of Ethics* for scientist in the case of Earthquake Predictions and the *European Advisory and Evaluation Committee for Earthquake Predictions*. He has also been used by EU as an expert in topics of Civil Protection and Seismic Hazard Research.

Current position: Graduate Professor of Structural Analysis:
1. School of Civil Engineering, National Technical University of Athens, Greece
2. Hellenic Open University

Honors:

1. Honorary President of the Hellenic Society of Theoretical and Applied Mechanics, February 2014.
2. Member of the Academia Europaea, elected on September 11, 2012.
3. Member of the European Academy of Sciences and Arts. (Academia Scientiarum et Artium Europea). The Official award ceremony of the Diploma took place in Salzburg on March 6, 2010.
4. Member of the European Academy of Sciences (EAS), November 18, 2010.
5. Corresponding Member of the International Academy of Engineering, (Seated in Moscow). Международня Инженерная Академия, москва, elected on February 26, 2010.
6. Doctor Honoris Causa (Honorary Doctor) of the University of Nis, Serbia. May 2009.
7. Honorary member of the *Polish Society of Theoretical and Applied Mechanics*, 2011.
8. Honorary member of the *Serbian Society of Mechanics* (2007).

9. Recent Developments in Boundary Element Methods: A Volume to Honour John T. Katsikadelis. WitPress, 2100, U.K.
This volume is dedicated to Prof. J.T. Katsikadelis on the Occasion of his 72 Birthday. Special talk in: http://www.wessex.ac.uk/general-news/eulogy-to-john-katsikadelis.html
10. Referee for the Queen Elizabeth Prize for Engineering 2013
11. President of the *Hellenic Society of Theoretical and Applied Mechanic*s (HSTAM), 2007-2010.
12. President of the *Greek Association for Computational Mechanics* (GRACM), affiliated to IACM (*International Association for Computational Mechanics*), 1997-2000 (twice elected).
13. General Secretary of the *Office of Theoretical and Applied Mechanics of the Academy of Athens*.
14. Member of the General Council of the *International Association for Computational Mechanics* (IACM).
15. Member of the *General Assembly of IUTAM* and *Representative of HSTAM in IUTAM*.
16. Fellow of the *Wessex Institute*, UK (for "*his outstanding contribution to the development of the Boundary Elements"*).
17. Award plaque *Honoris Causa* by the General Staff of the Greek Army for *his ten year contribution as a professor to the School of the Corps of Engineers*, 1986.
18. Award plaque *Honoris Causa* by the General Staff of the Greek Army *for his contribution as professor to the School of the Corps of Engineers* in Special ceremony on the occasion of his retirement, February 18, 2009.
19. Member of the ECCOMAS Committee on *Computational and Applied Mathematics*.
20. Thomaidio Award 2008 of NTUA for the best paper published in the Proceedings of International Conference (Paper No. 110)
21. Award plaque of the Greek Army on the 180th Anniversary Commemoration of the establishment of the Corps of Engineers for his contribution as a professor at the School of the Corps of Engineers, 18 November 2009.

Distinctions:

- Member of the editorial board of the Journals:
  - *Engineering Analysis with Boundary Elements*
  - *Technica Chronica*
  - *Boundary Element Communications*
  - *Facta Universitatis of the University of Nis, Series Architecture and Civil Engineering*
  - *The Open Mechanics Journal*
  - *International Journal for Engineering Analysis and Design*
- Fulbright Research Scholar for One-Year Visit as Postdoctoral Research Fellow at the Polytechnic University Of New York (1974-75)
- Chairman or Co-chairman of the Conferences and Symposia:
  - *3rd National Congress on Computational Mechanics, Volos Greece, June 24-26, 1999.*
  - *International Symposium on Recent Advances in Mechanics*: In Honor of Prof. A.N. Kounadis, Athens, Greece, November 25, 2000.
  - *23rd International Conference on Boundary Elements Methods, Lemnos, Greece May 7-9, 2001.*
  - *5th German-Greek-Polish Symposium on Advances in Mechanics, Bad Honnef, Germany, September 12-17, 2004.*
  - *28th International Conference on Boundary Elements and other Mesh reduction Methods, Skiathos, Greece, May 10-12, 2006.*
  - *6th German-Greek-Polish Symposium, on Advances in Mechanics, Alexandroupolis, Greece, September 17-21, 2007.*

- o *3rd Serbian-Greek Symposium "Recent Advances in Mechanics", Novisad, Serbia , September 15-17, 2008*.
- Listed in *Who's Who in The World 1993-1994*, 11th Edition, *Who's Who in Science and Engineering 1994-1995,* 2nd Edition, *Dictionary of International Biography 1995*, 23rd Edition.
- Man of the Year 1993 for "*His Outstanding Accomplishments to date and the Noble Example his has set for his Peers and Entire Community*", (American Biographical Institute).
- International Man of the Year 1992-1993 in "*Recognition of his Services to Engineering and Technology*, (International Biographic Center of Cambridge, England).
- Member of the Editorial Board of the international Series:
  - o *Boundary Element Series*, Computational Mechanics Publications
  - o *WIT Transactions on Modelling and Simulation*, WIT press
- Guest editor of the special issues of the Journals
  - o *Engineering Analysis with Boundary Elements*, Special Issue on Plates, Vol. 17 (2), pp. 91-181, 1996.
  - o *Engineering Analysis with Boundary Elements*, Special Issue on Nonlinear BEM, Vol. 23, (5-6), pp. 363-525,1999
  - o *Engineering Analysis with Boundary Elements*, Special Issue on BEM/MRM for inhomogeneous Solids, Vol. 32 (12), pp.995-174 (2008).
  - o *Archive of Applied Mechanics*, Special Issue on the 5th German-Greek-Polish Symposium on Advances on Mechanics, Vol. 74(11-12) pp. 729-898 (2005).
  - o *Archive of Applied Mechanics*, Special Issue on the 6th German-Greek-Polish Symposium on Advances on Mechanics, (Vol. 79(6-7), pp. 479-677, (2009).
- PhD Thesis advisor after invitation of the King Mongut's University of Technology Bangkok, Thailand.
- Member of the "P.S. Theocaris" Foundation, Treasurer, (2005-2007)
- Member of the *Committee of the Basic Research* of the National Technical University of Athens
- Founding Member of the ESDEP (*European Steel Design Programme*) and Member of WG 8
- Member of the *Technical Council of the Academy of Athens* (2000-present)
- Member of the Executive Council of *Institute of Engineering Seismology and Earthquake Engineering* (ITSAK) (1989-1992).
- Member of the international committee of the Council of Europe for the preparation of the *European Code of Ethics in Earthquake Prediction* (1990-91).
- Member of the EU Committee of specialists for the *Multilingual Lexicon of Civil Protection* (1991).
- Member of the ECCOMAS Committee on Computational and Applied Mathematics.

Membership in Scientific Societies:

- Member of the *Hellenic Society for Theoretical and Applied Mechanics* (HSTAM), affiliated to IUTAM, Treasurer (1986-2000), Vice President (2000-2007) and President 2007-present.
- Member of the *Greek Association for Computational Mechanics* (GRACM), affiliated to IACM. President 1997-2000. Founding member and member of the Administrative Council until present.
- Fellow of the Wessex Institute, UK.
- Honorary Member of the *Serbian Society of Mechanics* 2007.
- Member of the General Council of the *International Association for Computational Mechanics* (IACM) 2003-present.
- Founding Member of the of the *International Society for Computational Engineering and Sciences* (ISCES),

- Member of the Administrative Council of *International Society of Boundary Elements* (ISBE).
- Member of the *New York Academy of Sciences*.
- Member of the *Greek Society for Earthquake Engineering*.
- Founding Member of the *Hellenic Society for Steel Structures Research*.
- Member of the *ECCOMAS Committee on Computational and Applied Mathematics*.
- Member of the *Technical Chamber* of Greece.
- Member of the *Greek Society of Civil Engineers*.
- Member of the *American Society of Civil Engineers* (ASCE).
- Member of *Alumni Association of the Poly* (Polytechnic University of New York).
- Member of the Scientific Research Society *Sigma Xi*

Eulogy to John Katsikadelis:
The 9th Hellenic Theoretical and Applied Mechanics Congress recently took place in Limassol, Cyprus (no date given, perhaps circa 2008), and was the occasion for holding a special session to honour the work of Professor John Katsikadelis who is retiring from the National Technical University of Athens. A special book was edited for the occasion by Professor Evangelos Sapountzakis and published by the Wessex Institute of Technology's WIT Press [in 2010]. The book was presented to John at the Conference. The new volume contains a chapter reviewing John's work and the influence he has had in the field of Applied and Computational Mechanics. Professor Carlos A Brebbia, Director of Wessex Institute of Technology and friend of John for many years, gave a short presentation describing John's scientific career and highlighting the importance of his work. [See the book of the conference proceedings: Sapoutzakis, E.J. (Editor) (2010) "Recent Developments in Boundary Element Methods, A volume to Honor Professor John T. Katsikadelis", WIT Press, ISBN: 978-1-84564-492-5, 416 pages]

Special Talk in Praise of John Katsikadelis entitled **"A Well-Deserved Eulogy"**, by Carlos A. Brebbia, Wessex Institute of Technology, UK
It is always a difficult task for any scientist to review and comment on the career of a friend and colleague, particularly one who has been so creative and productive as John Katsikadelis. It is thus with trepidation that I write this eulogy of John's achievements trying to focus on what I consider to be the most original aspects of his work and apologising at the outset for any omissions undoubtedly due to the great quantity of material that John has contributed to engineering sciences and in particular to the development of advanced computational techniques including, but by no means exclusively, boundary elements.

The magnitude of my task can be judged by the over 200 high quality papers published by John, many of them on Boundary Elements, integral equations and other mesh reduction methods.

John introduced, at an early stage, the study of boundary elements to the School of Civil Engineering at the National University of Athens in the form of graduate and undergraduate courses, as well as setting up a research group that has achieved international recognition. His efforts in this regard, culminating in the publication of his book "Boundary Elements, Theory and Applications" [1] which has been published not only in Greek and English but also in Japanese (2004) and Russian (2007); reaching in this manner a vast audience and establishing his group amongst the most active BEM research centres in the world.

John's early training as a Civil Engineer at the National Technical University of Athens (NTUA) and in mathematics at the University of Athens was followed by two PhD degrees, one at NTUA and the other at the renowned Polytechnic University of New York at Brooklyn (majored in Continuum Mechanics, Applied Mathematics and Advanced Dynamics); both of them excellent preparation for a life dedicated to education and research.

His firm grasp of the more theoretical aspects of engineering has not detracted from his emphasis on solving practical applications – a fact reinforced by the period that he spent (for an academic) working as a professional civil engineer, specialising in structural design. This crucial period in between his two PhD degrees, reflects in the focus of his research in solving real, rather than academic, engineering problems.

There are many honours and distinctions that John has accumulated in his intensive professional and academic life; he has served on important committees; has been a member of the Editorial Board of prestigious journals; been a Committee Member or Chairman of important conferences and has served the community and science in numerous other ways. Those activities include some in which I have participated, such as being a member of the Editorial Board of the International Journal of Engineering Analysis with Boundary Elements and Chairman of several international Boundary Element Conferences. His involvement in all those activities has been, as is always the case with John, most thorough and included, among others, being Editor of Several Conference Proceedings [2] [3] and three times Guest Editor of special issues prepared for the Engineering Analysis with Boundary Elements Journal [4] [5] [6].

It is my intention in these few pages to concentrate on the originality of John's output which covers topics related to Computational Mechanics, in the area of BEM and Meshless Methods applied to solving linear and non-linear problems, under static and dynamic loads. He has made significant contributions in the fields of plate bending, structural shape optimisation, stability of structures, inverse problems and response of structures to non-conservative loads. More recently, he has been investigating the numerical solution of fractional differential equations and studying the response of structures under fractional type inertia and damping forces; topics which serve to indicate the continuous and uninterrupted evolution of John's scientific thoughts.

His interest in Boundary Elements started when reading a paper that was seminal to the development of several groups that were to contribute to the development of the method. This was the paper by M. Jaswon and R. Ponter on Integral Equation Solutions of Torsion Problems [7], where the basis of the direct BIEM formulation for potential problems were first established. Maurice Jaswon's interpretation of Green's formulae for those cases later led to the development of the direct boundary integral formulations in terms of Somigliana's identity for the stress analysis case. A few people around the world – including our own UK school and another in the USA - realised the importance of this work and it does John great credit that he also understood that the basis had been set up for a promising computational method. John applied the new ideas to the solution of the biharmonic equation for stress functions in plane elastostatic problems in preference to the more popular Muskhelisvili's complex variable formulation. This resulted in his early (1977) paper in Mechanics Research Communications [8]. In this paper, he presented for the first time the derivation and use of the integral representation of the normal derivative in the form of a boundary integral equation.

The formulation was later on applied by different authors after John's pioneering development. This was at a time when the interest in finite elements precluded further research or rested importance to any work done on other types of numerical methods.

John nevertheless saw the potential of boundary integral formulations and continued to develop his ideas further in his second Doctoral dissertation submitted at Brooklyn Polytechnic [9]. In this thesis, he presented the

Boundary Integral Equation Method for Plates on Winkler's Foundation, deriving the corresponding fundamental solution and obtaining accurate numerical results.

As Boundary Elements became better known, John's work on plate bending started to receive the recognition that it was due. His Brooklyn thesis produced two important papers, one dealing with clamped plate analysis on elastic formulations, published in ASME Transactions [10] and the other on plates with different boundary conditions published in the ASCE Journal of Engineering Mechanics [11]. At that time, those journals were the most prominent publications for mechanical sciences.

These early papers were followed by others dealing with the applications of boundary integral equations to plates resting on other types of elastic subgrade. He derived the fundamental solution for the case of two parameter soil model as well as the corresponding boundary integral solution, resulting in another two important papers [12] [13].

John's continuous interest in plate bending led to him proposing new formulations, including one based on the use of Reissner's plate model [14] [15]. The solution in this case was expressed in terms of two potentials, one biharmonic and the other, Bessel's, resulting in an original approach which produced accurate numerical results. It also demonstrated that Reissner's theory could be applied for a wide range of plate thicknesses, ranging from very small values to large ones without apparent loss of accuracy.

John contributed to the solution of many other plate bending problems. For instance, he published the first integral equations paper dealing with large deformation analysis of plates of uniform thickness with arbitrary geometry and boundary conditions [16] [17].

A complete review of John's work on plate bending would require considerable space as his work in this field has been most productive. His contribution is described in more detail in the Chapter on "Special Methods for Plate Bending" that has been published in reference [18]. This plate bending work precludes some of his more recent highly original contributions to be shortly described. John's contribution to our current understanding of boundary integral solutions for plate bending needs to be stressed and given proper recognition.

In the years that followed, John applied the BEM to solve a variety of problems, static and dynamic, whose fundamental solution could not be easily established (such as is the case of governing equations with variable coefficients); problems for which that solution may have been difficult to compute (such as dynamic problems) or others for which no solution existed (most nonlinear cases). John's approach was to use a simple fundamental solutions in all cases, i.e. Laplace for second order equations and that of the biharmonic operator for fourth order equations.

I met John for the first time in a series of lectures organised at CISM (Centre for the Study of Mechanical Sciences) in Udine in 1983 and there we discussed the importance of using simple fundamental solutions at the same time as allowing for all domain terms to be taken to the boundary, without the need to carry out domain integrations. This idea was the basis of the Dual Reciprocity Method (DRM) which I published in 1982 [19]. John promptly realised the need to use simple fundamental solutions if we were to extend the range of applications of BEM and in his characteristic manner, he went a step further and developed a more general version of the idea.

To better understand the importance of John's contribution, I will briefly explain the fundamentals of the

DRM. The method has two important steps, the first of which is the splitting of the governing equations of the problem into two parts one of which represents the terms for which a fundamental solution can be postulated, while the other groups those terms that are not part of that solution. Those terms represent fictitious boundary effects or domain sources and may result from nonlinear or time dependent effects which cannot be dealt with by the fundamental solution. The second important step of the DRM is to express those terms approximately, expanding them in terms of localised functions. The localised functions can be interpreted as defining the non-homogeneous terms of the same known (and usually simple) operators used in the first step. This results in the possibility of finding a series of localised particular solutions through which the domain sources can be taken to the boundary using the same integral identities applied when dealing with the fundamental solution used for the first step.

The DRM is quite general and produces boundary only solutions for those cases for which a linear operator with a well known fundamental solution could be extracted for the full governing equations. This, John realised, is not always possible, say for the case of partial differential equations with variable coefficients for instance.

Hence John developed the concept of the Analog Equation according to which a problem governed by linear or non-linear differential equations of any type (elliptic, parabolic or hyperbolic) can be converted into an analog problem described by an equivalent linear equation with a simple known fundamental solution of the same order as the original equation subjected to fictitious sources, unknown in the first instance. The value of these sources can be established using BEM. By applying this idea coupled linear or nonlinear equations can be converted into uncoupled linear ones for instance. The Analog Equation Method (AEM) only requires that the derivatives in the new equations are of the same degree as the original equations. If the higher derivatives are fourth order as in the case of plate bending, the same degree ought to apply to the proposed equation in the AEM. John's idea which was truly original has a wide range of important applications.

At first, John applied the AEM without reference to the possibilities of using the localised interpolation functions described in Step 2 of the DRM. Because of that, fictitious terms needed to be computed in the domain, either using standard FEM technique or the domain type cells appearing in some forms of classical BEM.

John's AEM idea was published for the first time in the 1993 Boundary Element Conference [20] and fully developed in his keynote address at the next meeting – 1994 – in that series of conferences [21]. AEM was then fully explained and I cannot do better than quote his words from that seminal paper:

"The unknown source density function is established numerically by adhering to the following steps.

a. The integral representation of the field function is established from the equivalent fictitious linear problem which involves the unknown source density in the domain integral.

b. Direct differentiation of this integral representation yields the derivatives involved in the operator of the real problem.

c. Use of BEM technique for the boundary integrals and FEM technique for the domain integrals yields the discretized expressions for the field function and its derivatives.

d. Collocation of the field function at the boundary and domain nodal points, collocation of the derivatives at the domain nodal points and elimination of the boundary quantities making use of the boundary conditions, yield the nodal values of the field function and its derivatives in terms of the values of the fictitious source density function at the nodal points inside the domain.

e. Application of the governing equation of the real problem at the nodal points inside the domain and substitution of the relevant values of the field function and its derivatives yields a system of algebraic equations (linear or non-linear, depending on the operator of the real problem) from which the nodal values of the fictitious source density function are established.

f. The field function and its derivative at any point inside the domain are obtained from their integral representation of the fictitious problem.

In differentiating the integral representation of the field function singular and hypersingular domain integrals arise which are evaluated efficiently by converting them to regular boundary integrals.

The method has the best features of the established computational methods, FDM, FEM, BEM and DRM. It combines their merits and circumvents their drawbacks.[22]

The concept of the Analog Equation in conjunction with integral techniques rendered the BEM a more efficient and versatile computational tool for solving different linear and nonlinear engineering problems using simple and well-known fundamental solutions.

An interesting application of the method was first presented in reference [23] in which the AEM was employed for system identification. In this case, AEM was used to identify constitutive material laws, including constant or varying parameters, ie those depending non-linearly on the unknown field functions and its derivatives. The examples presented in the paper included temperature distribution problems in non-homogeneous bodies, cases of temperature dependent thermal conductivity as well as nonlinear steady-state Burger's equation type flow. This application of the AEM may prove to have important implications, because it opens the way to formulate mathematically, i.e. establish the governing differential equations (deterministically or stochastically), the response of physical systems that are described by unknown physical principles and constitutive laws (e.g. composite materials [24], air pollution, wave propagation in bodies with unknown physical structure such as seismic waves) or systems that are not governed by physical laws at all (e.g. economic or other social sciences). We all know that during the last three centuries the effort was given to solve the differential equations resulting from rather simplified physical laws. Efficient solution methods of the established equations have been already developed. However, a question arises: "Do these equations approximate the actual response of the physical system reliably and realistically? "Therefore the problem of establishing the actual differential operator that models a system is apropos and a subject for future research. The AEM can give can give an answer to this problem.

Another provocative rather but interesting application of the AEM is the solution of "Equationless Problems Using Only Boundary data."[25,26], that is problems whose equation is unknown but we know all boundary data, imposed and resulting from the response, that is both Dirichlet and Neumann BCs at each point on the boundary.

An important special issue dealing with Plate Analysis and edited by John was published in 1996 in the Engineering Analysis with Boundary Elements Journal. There he has a paper extending the AEM to the dynamic analysis of plates with variable thickness [27]. He demonstrated that the fourth order partial differential equation with variable coefficients giving the dynamic response of the plate could be substituted by an equivalent quasi static plate bending problem with constant thickness subjected to a fictitious time-dependent load. In this case, singular and hypersingular integrals ought to be evaluated on internal cells; but John simplified the problem by transforming the domain singular integrals into regular integrals on the boundary of each cell using Green's reciprocal identity.

In 1997, John extended his AEM to solve a case previously never attempted, using BEM, i.e. the buckling of a plate with variable thickness [28]. The original eigenvalue problem for the differential buckling equation was substituted by a classical linear eigenvalue problem with discrete value of the fictitious load, from which the buckling loads were established numerically. Furthermore, also in 1997, the AEM was applied to study vibrations of plates with variable thickness subjected to in plane force, giving also excellent results [29].

Until then, the domain integrals in AEM were computed using either finite elements or the domain cells of classical BEM. In 1998 [30] John presented the first paper in which the use of the Radial Basis functions of DRM were applied in his method together with the concept of localised particular solutions. These concepts have been described in a general way in 1992 [31] but without reporting the wide range of application that were offered by the AEM. John was the first to combine the Analog Equation Method with the use of localised particular solutions. The methodology was generalised in a subsequent paper that appeared in the special issue on nonlinear BEM that he edited in 1999 for the Engineering Analysis with Boundary Elements Journal [32].

In this work, the distribution of the fictitious domain sources of AEM were approximated by the type of radial basis functions used in DRM. The solution of the analog equation was obtained as the sum of the homogenous and a particular solution. Then the non-homogeneous terms, i.e. the field function and its derivatives were expanded in terms of unknown series coefficients which were found by collocating the equation at a series of discrete points in the domain. The AEM hence became a truly boundary only method in the sense that only boundary discretisations are required.

This latest version of AEM has been successfully applied by John to solving several complex engineering problems, such as static and dynamic large deflection analysis of non-homogeneous anisotropic membranes [33] [34], nonlinear dynamic analysis of heterogeneous orthotropic membranes [35], space membranes [36], membranes subjected to ponding loads free [37] and floating in a liquid [38], static and dynamic analysis of rib-reinforced plates [39],[40],[41], the optimum design of structures subjected to follower loads [42] and other equally novel applications, including papers on linear and nonlinear flutter instability of damped plates [43], [44], plate thickness optimization problems [45] and a generalized Ritz method in domains of arbitrary shape using global shape functions [46].

The importance of the Analog Equation Method is its generality and that it opens up new possibilities and a better understanding of how to apply numerical methods. It also reveals a touch of genius in John's work.

To understand its implications, nothing is more appropriate than to revisit basic principles and in particular the work of another famous Greek author, Aristotle, who can be regarded as the originator of the idea of virtual work. In his renowned book, Physics, the philosopher stated that the behaviour of physical systems could be expressed in terms of 'potentialities' and 'actualities'. In other words, he set up the basis of the principle of virtual 'potentialities' or what we now call principle of virtual work. While the 'actual' field functions are to satisfy the equations governing the problem; the 'virtual' function can be much more general. Usually, we assume that they also satisfy the same equations as the actual field, or in the case of DRM, some reduced version of these equations. John instead stated that they do not need to necessarily satisfy the same type of governing equations as the actual problem, provided they have the necessary degree of continuity (say order fourth for plate bending, etc).

More recently, John has extended his AEM idea by using the type of Multiquadraic (MQ) type of functions proposed by Kansa [47] [48] but using them in a DRM type formulation. This avoids the primary disadvantage of the classical MQ scheme, i.e. that of being a global method and hence resulting in full coefficient matrices which suffer from ill-conditioning, particularly as their rank increases. This is a serious disadvantage that complicates the implementation of the MQ Method. Moreover, the performance of the classical MQ method depends on the shape parameter of those functions which are chosen empirically, a process that makes the technique problem dependent.

Instead, John uses the MQ function in the same way as classical radial basis functions are applied in AEM and DRM. He called the new technique Meshless Analog Equation Method (MAEM), which exhibits key advantages over other Radial Basis functions collocation methods in that the method is highly accurate and the matrix of the resulting system of equations is always invertible. The new Radial Basis functions (RBFs) resulting from the integration of MQs permit a strong formulation of the solution. Furthermore, it has a further advantage over Kansa's Method in that the derivatives of the equation after collocation are at most MQs. The accuracy is increased when using optimal values of the shape parameters of the multiquadrics.

This optimisation is possible by minimising the functional that produces the partial differential equations governing the problem [49] [50] [51]. In theory, the optimisation could include the position of the collocation points as well but this is seldom necessary and would give rise to lengthier calculations.

The advantages of the MAEM method as summarised by John are:

- Since the method allows the control of the condition number, an invertible coefficient matrix for the evaluation of the new RBFs expansion coefficients can always be established.
- The Method gives good results, because the new type of Radial Basis function resulting from the integration of the MQ function approximates accurately not only the solution itself, but also its derivatives.
- Optimum values of the shape parameter can be established when minimising a functional that yields the particular differential equations governing the problem (the position of the collocation points could also be optimised if necessary). Therefore, the uncertainty of choice of shape parameter is eliminated.
- As in the case of AEM, the MAEM method depends only on satisfying the order of the differential operators and not on the operator for the specific problem.

The method can be employed for the solution of other types of problems as well as those already presented for the AEM. The method has been already employed for the solution of several problems described by second and fourth order partial differential equations, such as 3D analysis of thick shells [52], 3D elastostatic problem for inhomogeneous anisotropic bodies [53] and plate problems [54].

John's ever-active mind is currently interested in the role of fractional derivatives in mechanics, and their importance in order to describe realistically the response of emerging materials and processes. The use of such concepts leads to fractional partial differential equations which after discretising the continuum, provides ordinary differential equations with fractional derivatives. John has developed a numerical method for solving linear and nonlinear multi-term fractional differential equations by extending the AEM in conjunction with a novel integral equation solution [55].

He has applied the method to solve a whole range of problems, including the fractional wave-diffusion equations [56]; the post buckling response of viscoelastic plates; the non-linear vibrations of viscoelastic membranes [57]; the non-linear vibrations and resonance of viscoelastic plates [58]. In all these cases, the viscoelastic method is described using a fractional derivative model. This pioneering work opens the way for solving a whole range of new problems.

In summary, the range of interests and novel ideas developed by John over his scientific and academic career is truly outstanding and has secured him a place among the main computational mechanics scientists in the world. He is particularly prominent among those researchers who have been actively involved in finding new methods to replace the classical mesh dependent techniques, most frequently used in engineering practice, such as FDM and FEM. This led to his early interest in BEM and more recently to his work on other mesh reduction and meshless methods.

John's other great virtue has been his intellectual generosity in sharing his knowledge with colleagues and researchers, contributing to creating a unique School of Computational Mechanics in Greece. His group is now recognised throughout the world for the excellence of their work, and this is the best legacy that John could give to his country and the world.

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