Αρχιμήδης ΙΙΙ – Ενίσχυση ερευνητικών ομάδων στο ΤΕΙ Αθήνας

ΠΡΟΣΚΛΗΣΗ ΣΕ ΔΙΑΛΕΞΗ

του Καθηγητή **Γεράσιμου Α. Αθανασούλη**

Τομέας Ναυτικής και Θαλάσσιας Υδροδυναμικής
Σχολή Ναυπηγών Μηχανολόγων Μηχανικών
Εθνικό Μετσόβιο Πολυτεχνείο (Ε.Μ.Π.)
mathan@central.ntua.gr
http://users.ntua.gr/mathan/index.html

Ο διακεκριμένος καθηγητής Γεράσιμος Α. Αθανασούλης της Σχολής Ναυπηγών Μηχανολόγων Μηχανικών του Εθνικού Μετσοβίου Πολυτεχνείου θα δώσει την Τετάρτη 24 Ιουνίου 2015 διάλεξη στο Τεχνολογικό Εκπαιδευτικό Ίδρυμα (Τ.Ε.Ι.) της Αθήνας σχετικά με θέματα της πρόσφατης έρευνάς του.

Η παρουσίαση αυτή είναι στα πλαίσια της συμμετοχής του στην κύρια ερευνητική ομάδα του προγράμματος με τίτλο *«Υδροελαστική απόκριση μεγάλων πλωτών κατασκευών και σωμάτων γενικού σχήματος σε περιβάλλον μεταβαλλόμενης 3D βαθυμετρίας»* του «ΑΡΧΙΜΗΔΗΣ ΙΙΙ» (Υποέργο 29, HydELFS) και σε συνεργασία με το *Εργαστήριο Εφαρμοσμένης Μηχανικής* του ΤΕΙ της Αθήνας.

Η διάλεξη θα δοθεί την **Τετάρτη 24 Ιουνίου 2015**, ώρα 13:00 με 14:30, στην Αίθουσα Υδραυλικής της Σχολής Τεχνολογικών Εφαρμογών του ΤΕΙ της Αθήνας (Κτίριο Κ10) με τίτλο:

> ***Variational formulation of the Nonlinear Water-Wave Problem over arbitrary smooth bathymetry. Thoeretical background and numerical solution.***

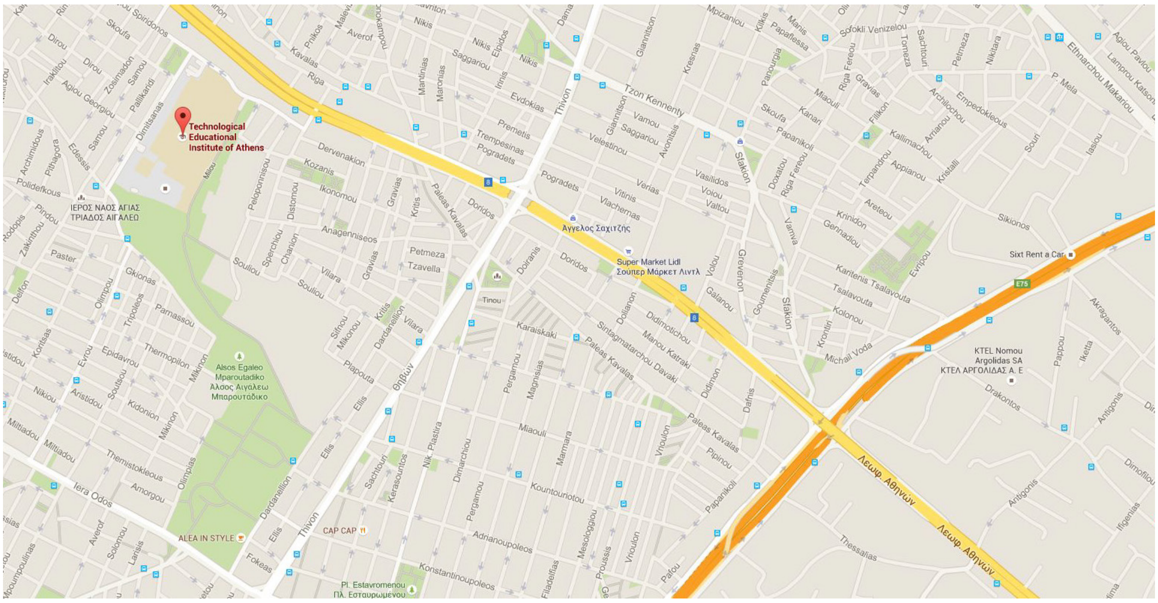
Σύντομη περιγραφή του περιεχομένου της διάλεξης του Καθηγητή Γερ. Αθανασούλη καθώς και οδηγίες πρόσβασης στο ΤΕΙ της Αθήνας και το χώρο της διάλεξης επισυνάπτονται στην παρούσα πρόσκληση.

Για περισσότερες πληροφορίες μπορείτε να επικοινωνήσετε με τον Φίλη Κόκκινο, Τμήμα Πολιτικών Μηχανικών και Μηχανικών Τοπογραφίας & Γεωπληροφορικής του ΤΕΙ Αθήνας, τηλ. 6977285710, *fkokkinos@teiath.gr*

*Η παρούσα δράση έχει συγχρηματοδοτηθεί από την Ευρωπαϊκή Ένωση (Ευρωπαϊκό Κοινωνικό Ταμείο, ΕΚΤ) και από εθνικούς πόρους μέσω του Επιχειρησιακού Προγράμματος «Εκπαίδευση και Δια Βίου Μάθηση» του Εθνικού Στρατηγικού Πλαισίου Αναφοράς (ΕΣΠΑ) – Ερευνητικό Χρηματοδοτούμενο Έργο: **ΑΡΧΙΜΗΔΗΣ ΙΙΙ**. Επένδυση στην κοινωνία της γνώσης μέσω του Ευρωπαϊκού Κοινωνικού Ταμείου.*

Με τη συγχρηματοδότηση της Ελλάδας και της Ευρωπαϊκής Ένωσης

Πρόσβαση στο Τεχνολογικό Εκπαιδευτικό Ίδρυμα Αθήνας



[ΤΕΙ Αθήνας (Google Maps)]

Πύλες εισόδου και Αίθουσα Υδραυλικής

Variational formulation of the Nonlinear Water-Wave Problem over arbitrary smooth bathymetry. Thoeretical background and numerical solution

by

Gerassimos A. Athanassoulis
mathan@central.ntua.gr and makathan@gmail.com
School of Naval Architecture and Marine Engineering
National Technical University of Athens

Main collaborators: K.A. Belibassakis, Associate Professor, SNAME, NTUA
Th.P. Gerostathis, Assistant Professor, TEI
Ch. Papoutsellis, PhD Cand., SNAME, NTUA

Water waves, also called surface gravity waves, abound in the natural environment and their study is of central importance for coastal engineering, oceanography, ship and marine engineering, and offshore structures. The mathematical modelling of water waves is highly demanding since, even under the simplifying assumptions that the flow is inviscid and irrotational, the problem remains nonlinear and nonlocal, due to the free-surface conditions. The nonlocality of the problem, closely related with the dispersive character of water waves, comes from the fact that surface waves propagate in two horizontal dimensions, say x_1, x_2, although the hydrodynamic problem is three dimensional, involving the vertical coordinate, z, as well.

We consider here the problem of nonlinear, irrotational, water waves propagating over an arbitrary bathymetry, without any simplification concerning the shape (slope) of the free-surface elevation $z = \eta(\boldsymbol{x},t)$ and the seabed surface $z = -h(\boldsymbol{x})$. The incoming wave may be any nonlinear progressive wave system which has been generated in the incident region (e.g., an exact solution of the nonlinear problem over an horizontal seabed). The dynamical evolution of the nonlinear wave field and its interaction with the bathymetry is studied variationally, using an unconditional Variational Principle (LUKE 1967) which is reduced to Hamilton's Principle under the restriction on kinematics. The unconditional character of LUKE's Principle leaves us ample freedom regarding the representation of the wave potential $\Phi(\boldsymbol{x},z,t)$, which is a crucial point in constructing an efficient system of dynamical equations. To be more specific, while keeping full generality, the unknown wave potential is represented by a convergent, infinite series of the form

$$\Phi(\boldsymbol{x},z,t) = \sum_{n=-2}^{\infty} \varphi_n(\boldsymbol{x},t)\, Z_n(z;\eta(\boldsymbol{x},t),h(\boldsymbol{x})), \qquad (1)$$

where the vertical functions Z_n are explicitly prescribed functions of the vertical coordinate z and the local values of the free-surface elevation $\eta(\boldsymbol{x};t)$ and water depth $h(\boldsymbol{x})$, and the horizontal functions $\varphi_n(\boldsymbol{x};t)$ are unknown (to be determined) modal amplitudes. The key idea, dictating the structure of the series expansion (1), developed by Athanassoulis and Belibassakis in a series of papers [see, e.g., (AB-1999), (AB-2000), (AB-2007), (BA-2011)], is the enhancement of the convergence properties by using two unconventional modal fields ($n = -2, -1$), ensuring convergence up to and including the boundaries of the flow field, for any (smooth) surfaces $\eta(\boldsymbol{x};t)$ and $h(\boldsymbol{x})$. The vertical functions

$$\left\{ Z_n(z;\eta(\boldsymbol{x},t),h(\boldsymbol{x})),\ n = -2,-1,0,1,2,... \right\} \equiv \left\{ Z_n(z),\ n \geq -2 \right\}$$

are constructing so that to provide Riesz bases for the Sobolev spaces $H^2[-h(\boldsymbol{x}),\eta(\boldsymbol{x},t)]$ for each vertical interval $[-h(\boldsymbol{x}),\eta(\boldsymbol{x},t)]$. The estimates

$$\left\| Z_n(\cdot) \right\|_\infty = O(1) \ \text{ and } \ \left\| \varphi_n(\cdot;\cdot) \right\|_\infty = O\left(n^{-4}\right), \qquad (2)$$

(proven under the assumption that there exists a classical solution) ensure that the series expansion (1) is rapidly convergent, and can be integrated and differentiated term-by-term up to and including the boundaries, at least two times, validating the analytical treatment of the variational study of the problem (which follows).

Representation (1), in conjunction with the Variational Principle, leads to a semi-discretized problem (Kantorovich-type dimensional reduction), governed by an infinite system of variational equations with respect to the free-surface elevation $\eta(\boldsymbol{x};t)$ and the modal amplitudes $\varphi_n(\boldsymbol{x},t)$, $n \geq -2$. Further study of the structure of the variational equations reveals that they can be recast as two nonlinear, evolution, dynamical equations, with respect to the surface fields $\eta(\boldsymbol{x};t)$ and $\psi(\boldsymbol{x},t) = \sum_{n \geq -2} \varphi_n(\boldsymbol{x},t)$, which are not closed on their own, plus an infinite set of linear, spatial-partial differential equations (not including time differentiation), with respect to $\varphi_n(\boldsymbol{x},t)$, $n \geq -2$, which provide the closure condition (implemented by means of the field $\varphi_{-2}(\boldsymbol{x},t)$) to the two dynamical equations, at each time t. The relation of the present (exact) equations with various existing (approximate) model equations, such as mild-slope models or Boussinesq-type models, is discussed.

Numerical schemes have been developed for solving the two subproblems arising in our Hamiltonian reformulation of the nonlinear water-wave problem:

a) The infinite (truncated) system of time-independent, spatial-partial differential equations in the horizontal subspace (the substrate problem), and
b) The two Hamiltonian evolution equations (the evolution problem).

The substrate problem is numerically solved (after truncation to 3+*M* equations, which corresponds to keeping -2, -1, the propagating and *M* evanescent modes in the vertical series expansion (1)) by using 4th-order, central, finite-differences. The evolution problem is numerically solved by using the classic Runge-Kutta method. Systematic numerical investigation confirms the numerical convergence in general, and its (theoretical) rate (2) in particular. The approach is validated by means of detailed comparisons of the computed wave field with experimental results (physical measurements) for the case of the classical Beji-Battjes (BB-1993) experiment.

References

AB-1999: Athanassoulis, G.A. & Belibassakis, K.A., 1999. A consistent coupled-mode theory for the propagation of small-amplitude water waves over variable bathymetry regions. *Journal of Fluid Mechanics*, 389, pp.275–301.

AB-2000: Athanassoulis, G.A. & Belibassakis, K.A., 2000. A Complete Modal Expansion of the Wave Potential and Its Application to Linear and Nonlinear Water-Wave Problems. In *Rogue Waves 2000*. pp. 73–90.

AB-2007: Athanassoulis, G.A. & Belibassakis, K.A., 2007. New Evolution Equations For Non-Linear Water Waves in General Bathymetry With Application to Steady Travelling Solutions in Constant, But Arbitrary, Depth. *Discrete and Continuous Dynamical Systems*, SUPPLEMENT, pp.75–84.

BB-1993: Beji, S. & Battjes, J.A., 1993. Experimental investigation of wave propagation over a bar. *Coastal Engineering*, 19(1-2), pp.151–162.

BA-2011: Belibassakis, K.A. & Athanassoulis, G.A., 2011. A coupled-mode system with application to non-linear water waves propagating in finite water depth and in variable bathymetry regions. *Coastal Engineering*, 58(4), pp.337–350

Luke, J.C., 1967. A variational principle for a fluid with a free surface. *Journal of Fluid Mechanics*, 27, pp.395–397.