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Coupled acoustic response of two-dimensional bounded and unbounded domains using doubly-asymptotic open boundaries. (English) Zbl 1349.76181

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Summary: A high-order doubly-asymptotic open boundary for modelling scalar wave propagation in two-dimensional unbounded media is presented. The proposed method is capable of handling domains with arbitrary geometry by using a circular boundary to divide these into near field and far field. The original doubly-asymptotic continued-fraction approach for the far field is improved by introducing additional factor coefficients. Additionally, low-order modes are approximated by singly-asymptotic expansions only to increase the robustness of the formulation. The scaled boundary finite element method is employed to model wave propagation in the near field. Here, the frequency-dependent impedance of bounded subdomains is also expanded into a series of continued fractions. Only three to four terms per wavelength are required to obtain accurate results. The continued-fraction solutions for the bounded domain and the proposed high-order doubly-asymptotic open boundary are expressed in the time-domain as coupled ordinary differential equations, which can be solved by standard time-stepping schemes. Numerical examples are presented to demonstrate the accuracy and robustness of the proposed method, as well as its advantage over existing singly-asymptotic open boundaries.

MSC:

76M10 Finite element methods applied to problems in fluid mechanics
65M60 Finite element, Rayleigh-Ritz and Galerkin methods for initial value and initial-boundary value problems involving PDEs
76Q05 Hydro- and aero-acoustics

Keywords:

high-order open boundary; doubly asymptotic; circular cavity; exterior acoustics; continued-fraction expansion; scaled boundary finite element method

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References:

[1] (Marburg, S.; Nolte, B., Computational Acoustics of Noise Propagation in Fluids - Finite and Boundary Element Methods, (2008), Springer)

[2] Astley, R. J., Infinite elements for wave problems: a review of current formulations and an assessment of accuracy, Int. J. Numer. Methods Eng., 49, 951-976, (2000) · Zbl 1030.76028

[3] Gerdes, K., A review of infinite element methods for exterior Helmholtz problems, J. Comput. Acoust., 8, 43-62, (2000) · Zbl 1360.65248

[4] Berenger, J.-P., A perfectly matched layer for the absorption of electromagnetic waves, J. Comput. Phys., 114, 185-200, (1994) · Zbl 0814.65129

[5] Turkel, E.; Yefet, A., Absorbing PML boundary layers for wave-like equations, Appl. Numer. Math., 27, 533-557, (1998) · Zbl 0933.35188

[6] Harari, I.; Slavutin, M.; Turkel, E., Analytical and numerical studies of a finite element PML for the Helmholtz equation, J. Comput. Acoust., 8, 121-137, (2000) · Zbl 1360.76139

[7] Keller, J. B.; Givoli, D., Exact non-reflecting boundary conditions, J. Comput. Phys., 82, 172-192, (1989) · Zbl 0671.65094

[8] Grote, M. J.; Keller, J. B., Exact nonreflecting boundary conditions for the time dependent wave equation, SIAM J. Appl. Math., 55, 280-297, (1995) · Zbl 0817.35049

[9] Harari, I., A survey of finite element methods for time-harmonic acoustics, Comput. Methods Appl. Mech. Eng., 195, 1594-1607, (2006) · Zbl 1122.76056

[10] Lysmer, J.; Kuhlemeyer, R. L., Finite dynamic model for infinite media, J. Eng. Mech. Div., 95, EM4, 859-877, (1969)

[11] Engquist, B.; Majda, A., Radiation boundary conditions for acoustic and elastic wave calculations, Commun. Pure Appl. Math., 32, 313-357, (1979) · Zbl 0387.76070

[12] Bayliss, A.; Turkel, E., Radiation boundary conditions for wave-like equations, Commun. Pure Appl. Math., 33, 707-725, (1980) · Zbl 0438.35043

[13] Higdon, R. L., Absorbing boundary conditions for difference approximations to the multi-dimensional wave equation, Math. Comput., 47, 176, 437-459, (1986) · Zbl 0609.35052

[14] Collino, F., High order absorbing boundary conditions for wave propagation models: straight line boundary and corner cases, (Proceedings of the Second International Conference on Mathematical and Numerical Aspects of Wave Propagation, Newark, Delaware, (1993)), 161-171 · Zbl 0814.35065

[15] Hagstrom, T.; Warburton, T., A new auxiliary variable formulation of high-order local radiation boundary conditions: corner compatibility conditions and extensions to first-order systems, Wave Motion, 39, 327-338, (2004) · Zbl 1163.74364

[16] Givoli, D., High-order local non-reflecting boundary conditions: a review, Wave Motion, 39, 319-326, (2004) · Zbl 1163.74356

[17] Hagstrom, T.; Mar-Or, A.; Givoli, D., High-order local absorbing boundary conditions for the waves equation: extensions and improvements, J. Comput. Phys., 227, 3322-3357, (2008) · Zbl 1136.65081

[18] Bécache, E.; Givoli, D.; Hagstrom, T., High-order absorbing boundary conditions for anisotropic and convective wave equations, J. Comput. Phys., 229, 1099-1129, (2010) · Zbl 1181.65123

[19] Prempramote, S.; Song, C.; Tin-Loi, F.; Lin, G., High-order doubly asymptotic open boundaries for scalar wave equation, Int. J. Numer. Methods Eng., 79, 340-374, (2009) · Zbl 1171.74360

[20] Geers, T. L., Doubly asymptotic approximations for transient motions of submerged structures, J. Acoust. Soc. Am., 64, 1500-1508, (1978) · Zbl 0385.76081

[21] Underwood, P.; Geers, T. L., Doubly asymptotic boundary-element analysis of dynamic soil-structure interaction, Int. J. Solids Struct., 17, 687-697, (1981) · Zbl 0454.73074

[22] Geers, T. L.; Zhang, P., Doubly asymptotic approximations for submerged structures with internal fluid volumes: formulation, J. Appl. Mech., 61, 893-899, (1994) · Zbl 0829.76080

[23] Geers, T. L.; Zhang, P., Doubly asymptotic approximations for submerged structures with internal fluid volumes: evaluation, J. Appl. Mech., 61, 900-906, (1994) · Zbl 0829.76081

[24] Geers, T. L.; Lewis, B. A., Doubly asymptotic approximations for transient elastodynamics, Int. J. Solids Struct., 34, 1293-1305, (1997) · Zbl 0944.74570

[25] Geers, T. L.; Toothaker, B. J., Third-order doubly asymptotic approximations for computational acoustics, J. Comput. Acoust., 8, 101-120, (2000) · Zbl 1360.76198

[26] Birk, C.; Prempramote, S.; Song, C., An improved continued-fraction-based high-order transmitting boundary for time-domain analyses in unbounded domains, Int. J. Numer. Methods Eng., 89, 269-298, (2012) · Zbl 1242.74096

[27] Lin, G.; Wang, Y.; Hu, Z., An efficient approach for frequency-domain and time-domain hydrodynamic analysis of dam-reservoir systems, Earthq. Eng. Struct. Dyn., 41, 1725-1749, (2012)

[28] Song, C.; Wolf, J. P., Consistent infinitesimal finite-element-cell method: out-of-plane motion, J. Eng. Mech., 121, 613-619, (1995)

[29] Wolf, J. P.; Song, C., Consistent infinitesimal finite-element-cell method: in-plane motion, Comput. Methods Appl. Mech. Eng., 123, 355-370, (1995)

[30] Song, C.; Wolf, J. P., Consistent infinitesimal finite-element cell method: three-dimensional vector wave equation, Int. J. Numer. Methods Eng., 39, 2189-2208, (1996) · Zbl 0885.73089

[31] Wolf, J. P.; Song, C., Finite-element modelling of unbounded media, (1996), Wiley & Sons Chichester · Zbl 0879.73002

[32] Song, C.; Wolf, J. P., The scaled boundary finite-element method - alias consistent infinitesimal finite-element cell method - for elastodynamics, Comput. Methods Appl. Mech. Eng., 147, 329-355, (1997) · Zbl 0897.73069

[33] Wolf, J. P., The scaled boundary finite element method, (2003), John Wiley & Sons Ltd Chichester

[34] Vu, T. H.; Deeks, A. J., Use of higher-order shape functions in the scaled boundary finite element method, Int. J. Numer. Methods Eng., 65, 1714-1733, (2006) · Zbl 1115.74053

[35] Wolf, J. P.; Song, C., The scaled boundary finite-element method - a primer: derivations, Comput. Struct., 78, 191-210, (2000)

[36] Song, C., The scaled boundary finite-element method in structural dynamics, Int. J. Numer. Methods Eng., 77, 1139-1171, (2009) · Zbl 1156.74387

[37] Fan, S. C.; Li, S. M., Boundary finite-element method coupling finite-element method for steady-state analyses of dam-reservoir systems, J. Eng. Mech., 134, 133-142, (2008)

[38] Prempramote, S., Development of high-order doubly asymptotic open boundaries for wave propagation in unbounded domains by extending the scaled boundary finite element method, (2011), The University of New South Wales Sydney, Australia, Ph.D. thesis