T a g u n g s b e r i c h t 42 / 1994

Boundary Element Methods:
Applications and Error Analysis

3.–8.10.1994

The conference was chaired by Ernst P. Stephan (Hannover) and Wolfgang L. Wendland (Stuttgart). The participants' fields were computational mechanics and numerical and applied analysis. They came from ten different countries.
Whereas integral equations usually belong to the classical subjects of analysis, the boundary integral equations, as the result of the reduction to the boundary of boundary value problems of partial differential equations, are often of unconventional type and their computational solution has generated many particular features and questions which came up in this lively and busy conference, too. The following topics are closely intertwined and have found particular interest:

- formulation, functional analysis and algorithmic aspects of boundary integral methods; in particular for nonlinear problems (inverse scattering, free boundaries and seepage problems, hyperelastic, elastoplastic and viscoelastic deformations, compressible flows, nonlinear contact problems)
- boundary integral equations and boundary element methods for time–dependent problems (collocation methods for linear parabolic equations, even with moving boundaries, incremental methods in nonlinear elasticity and viscoelasticity, hyperbolic problems for electromagnetic fields, elastic vibrations in

anisotropic materials and asymptotic analysis of nonlocal artificial boundary conditions)

- the treatment of singularities (crack and punch problems including singular perturbations, reinforcements by stringers, contact including corners and edges between different materials, equations on Lipschitz curves)
- hypersingular equations and new analytic and algorithmic aspects for the computation of arbitrary derivatives on the boundary
- efficient solution algorithms with and for boundary element discretizations (multigrid and multilevel methods, preconditioning, finite- and boundary element coupling, hybrid methods, domain decomposition, parallel algorithms, data compression with spectral methods, wavelets and prewavelets, combined collocation and Galerkin treatment)
- error analysis, error control and adaptive boundary elements (qualocation, collocation together with numerical quadrature on polygonal and polyhedral domains, error analysis and adaptivity of h,p and h-p boundary element methods including local error control and indicators)

In fact, this was the first time that the mathematical problems in current boundary element research have been the main object of a conference. The participants gratefully enjoyed to meet specialists from so many different places all over the world. After lectures and during breaks many vivid discussions developed in a very cordial and stimulating manner, although the lecturing program was rather tight.
The wonderful atmosphere was also due to the staff and the director of the institute whom we all are thanking for the continuous, friendly and sometimes spontaneous care. I want to express the participants' gratitude to everybody who helped to make this unforgettable conference possible.

ABSTRACTS:

E.A. BADERKO (Moscow):

Parabolic problems and integral equations
In a noncylindrical domain Ω with "lateral" boundary Σ (which, in general, is not smooth) we consider the boundary value problem: $\mathcal{L}u = 0$ in Ω, $u|_{t=0} = 0$, $Bu = \psi$ on Σ, where $\mathcal{L}$ is a linear parabolic operator of second order with Hölder-continuous

coefficients, B is an operator defining the boundary condition of the first kind (I) or second kind (II).
In case (II), a nontangential directional derivative is given. The function ψ belongs to the anisotropic Hölder space $C^{1,\alpha}(\Sigma)$ (in case I) or $C^{0,\alpha}(\Sigma)$ (in case II). We show that this BVP has an unique solution $u \in C^{1,\alpha}(\bar{\Omega}) \cap C^{2,1}(\Omega)$. This solution is a single-layer potential with a density φ. The function $\varphi \in C^{0,\alpha}(\Sigma)$ is a solution of a corresponding Volterra boundary integral equation of the first kind (in case I) or second kind (in case II). There hold the natural estimates for $\|u\|$ and $\|\varphi\|$ by $\|\psi\|$ in corresponding Hölder spaces.

D. BERTHOLD and B. SILBERMANN (Technische Universität Chemnitz–Zwickau):

Corrected collocation methods for periodic pseudodifferential equations
In the approximative solution of periodic pseudodifferential equations $Au = f$, for example boundary integral equations, one is often interested in error estimates in Sobolev spaces of negative order. Unfortunately, the collocation method which is very favourable because of its rather easy implementation does not give sufficiently sharp convergence rates in these spaces.
As a new idea, to overcome this disadvantage (besides the qualocation method), we propose the corrected collocation method. Its main idea consists in correcting the collocation solution by the solution of a "small" Galerkin system for the same equation $Au = f$. If the coefficients of the pseudodifferential operator A are sufficiently smooth this approach leads to improved convergence rates. In many cases even the rate of the qualocation method is exceeded.
We have shown convergence theorems for both, trigonometric and spline (of arbitrary degree) approximation methods [1]. Note that the corrected collocation method also works in the case of non-constant coefficients of the pseudo A. The numerical experiments, which we have done, prove the theoretical results to be true.
REFERENCE:
[1] Berthold, D. and Silbermann, B.: Corrected collocation methods for periodic pseudodifferential equations, *Numerische Mathematik*, to appear.

C. CARSTENSEN (Heriot-Watt University, Edinburgh, U.K.):

On adaptive BEM
In works with E.P. Stephan, a-posteriori estimates for the (Galerkin) boundary element method (BEM) of first kind integral equations were obtained as for Symm's

integral equation, an integral equation with a hypersingular operator, and an integral equation for a transmission problem in 2D and 3D. The talk presented a simple abstract frame for deriving such estimates based on an interpolation estimate. Three a–posteriori error estimates were discussed for Symm's integral equation; two of them are sharp for uniform meshes at least. Having proved some a–posteriori computable bounds they are used to drive the mesh–refinement and to lead to self–adaptive schemes. The question of efficiency was addressed by numerical examples. Furthermore, for the collocation h–BEM and the (Galerkin) hp–BEM, similar estimates hold and related adaptive algorithms were presented. Numerical examples underlined their efficiency.

G. CHANDLER and L. FORBES (University of Queensland, Australia):

Fundamental solutions methods for free boundary problems
To solve potential problems, the fundamental solutions method approximates the solution by a sum of potentials due to sources outside the domain. The strength of these sources is computed by satisfying the given boundary data at collocation points on the boundary.
This simple method avoids the singular integrals of the boundary element method, but the collocation equations are very ill conditioned. Good approximations are obtained in practice provided the method is carefully tuned. It has proved particularly useful in solving free boundary problems.

S.N. CHANDLER–WILDE (Brunel University, Uxbridge, U.K.):

BIE methods for rough surface scattering: A model problem
We consider the two–dimensional problem of scattering of a plane acoustic wave by a straight boundary on which an impedance or third–kind boundary condition holds with arbitrary bounded spatially–varying impedance. This problem serves as a model of the more difficult problem of plane wave scattering by an infinite rough surface, in that in each case it is not clear how to formulate the problem, in particular, how to impose a radiation condition for the scattered field which allows developement of an appropriate uniqueness and existence theory. We propose a generalization of Sommerfeld's radiation condition which is sufficiently strong to enable Green's representation theorem to be derived in the exterior domain. For the model problem, we utilize this radiation condition to prove uniqueness of the solution and to derive an equivalent boundary integral equation formulation. The integral equation is of convolution type with coefficients. Using some recent results,

we deduce existence of the solution and derive stability and convergence rates for a boundary element solution method.

I.Y. CHUDINOVICH (Kharkov University, Ukraine):

The boundary equation method in electrodynamic problems for the Maxwell system

It is well known that the potential theory methods are of primary importance both in studying static and quasi-static problems of the diffraction of electromagnetic waves and in solving them numerically. There are numerous papers and monographs devoted to these questions. Now the interest increases for analogous methods for solving genuinely non-stationary problems approximately. In order to promote the further developement of corresponding numerical methods it would be very useful to construct a mathematically rigorous and sufficiently complete theory of non-stationary boundary equations for electrodynamic problems. The fact is that boundary equations in the non-stationary case differ essentially from the analogous static and quasi-static cases with respect to several properties. Moreover, these properties influence the convergence and stability of corresponding numerical solution algorithms.

In the lecture, the boundary equations of the so-called dynamical electric problems are considered. The solutions of these problems are presented in form of various combinations of the electric single- and double-layer potentials. The limiting transition of a point to the boundary surface in these representations leads to systems of non-stationary boundary equations. The aim of the talk is to present results of unique solvability of these systems in some function spaces of Sobolev type.

D.E. ELLIOTT (University of Tasmania, Australia):

The cruciform crack problem and sigmoidal transformations

In the first part of the lecture an algorithm for the approximate solution of integral equations of the form

$$w(t) - \int_0^1 h(t,s)w(s)ds = f(t),\ 0 < t \leq 1\,, \tag{1}$$

with h having a fixed singular point at $(0,0)$, was described. The cruciform crack (cross-shaped crack) problem of plane elasticity can be formulated as (1) with

$$h(t,s) = -\frac{4}{\pi}\cdot\frac{ts^2}{(t^2+s^2)^2}\,,\ f(t) = 1\,. \tag{2}$$

Of particular interest to elasticicans is the stress intensity factor $w(1)$.
The algorithm (see Elliott and Prössdorf [1]) depends on the use of a sigmoidal (S-shaped) transformation γ_r which is $1-1$ from $[0,1]$ onto $[0,1]$ where $r>0$, $\gamma_r(\tau) = O(\tau^r)$ near $\tau=0$ and $\gamma_r \in C^\infty(0,1)$. In particular, in [1] the transformation

$$\gamma_r(\tau) = \frac{\tau^r}{\tau^r + (1-\tau)^r}, \quad 0 \le \tau \le 1, \tag{3}$$

was used. With suitable changes of the dependent and both independent variables in (1), a new integral equation

$$\phi(\tau) - \int_0^1 k(\tau,0)\phi(0)do = F(\tau),\ 0 \le \tau \le 1, \tag{4}$$

is obtained where, if $r>1$ then, for example, $\phi(0)=\phi(1)=0$. Equation (4) is solved by a Nyström method based on a second sigmoidal transformation of the Euler–Maclaurin quadrature rule. It was pointed out that the proof of convergence of the algorithm depended upon the fact that the kernel K in (4) can be written as $L+M$ where M is continuous and L is that part of K near $(0,0)$ which can be majorized by a Mellin kernel with norm <1 in an appropriate normed space.
In the second part of the lecture, various other sigmoidal transformations were considered. Suppose Ψ_r is of the form

$$\Psi_r(\tau) = \frac{f_r(v_r(\tau))}{f_r(v_r(\tau)) + f_r(v_r(1-\tau))}, \quad 0 \le \tau \le 1, \tag{5}$$

then it was shown how, by different choices of the functions f_r and v_r, we can obtain the sigmoidal transformation due to Kress, Korolov, Sarg and Szekeres and Sidi (see[2]). Sidi has pointed out that for the "best" results with the modified Euler–Maclaurin quadrature rule, one needs Ψ_r such that, near $\tau=0$,

$$\Psi_r'(\tau) = \tau^{r-1}\{a_0 + a_1\tau^2 + a_2\tau^4 + \cdots\}, \tag{6}$$

where $r \in \mathbb{N}$ and r odd. Sidi gives such a transformation by choosing, in (5),

$$v_r(\tau) = \tau,\ f_r(\tau) = \int_0^\tau (\sin \pi\sigma)^{r-1} d\sigma. \tag{7}$$

The lecture concluded by presenting numerical results for $w(1)$ using this transformation which justifies Sidi's observation.

REFERENCES:

[1] D. Elliott and S. Prössdorf: An algorithm for the approximate solution of integral equations of Mellin type, *Numerische Mathematik*, to appear.

[2] Avram Sidi: A new variable transformation for numerical integration, ISNM **112**, pp 359–373, Birkhäuser Verlag, Basel (1993).

L. GAUL (Universität Stuttgart):

Calculation of viscoelastic members by boundary element methods in time domain

The boundary element method (BEM) provides a powerful tool for the calculation of elastodynamic response in frequency and time domain.

Field equations of motion and boundary conditions are cast into boundary integral equations, which are discretized in space and time. The unknown boundary data often are of primary interest because they govern the transfer dynamics of members and the energy radiation into a surrounding medium.

In the present paper, viscoelastic material behaviour is implemented in a time domain approach as well. The constitutive equations are generalized by taking fractional order time derivatives into account. Improved curvefitting properties and the fullfilment of causality requirements are demonstrated.

A near hybrid symmetric boundary element formulation based on a multifield variational principle was outlined and documented by results of boundary and domain variables of a dynamically loaded system.

The question of instability and numerical damping was raised for time stepping algorithms. For an elastic continuum, the BE response leads to instability if small time steps below a critical value are chosen.

Replacement of derivatives of the fundamental solution with respect to time by those with respect to space associated with their finite difference approximation of higher order increases the stability range and reduces the numerical damping.

REFERENCES:

Gaul, L. and Schanz, M.: Dynamics of viscoelastic solids treated by boundary element approaches in time domain. *European Journal of Mechanics*, A/Solids, Vol. 13, N° 4–suppl, 43–59, 1994.

Ricoeur, A.: Entwicklung einer hybriden Randelementmethode in der Elastodynamik. Master thesis, Institute A of Mechanics, Stuttgart University, Sept. 1994 (unpublished).

I.G. GRAHAM (University of Bath, U.K.):

Quadrature methods for Symm's integral equation on polygons

In a recent joint paper with J. Elschner the author obtained stability and convergence results for spline collocation methods of arbitrarily high order applied to the classical first-kind boundary integral equation with logarithmic kernel (Symm's equation) on a polygonal domain. The talk summarizes these results and obtains the same convergence results for the method when the collocation integrals are approximated using an appropriate quadrature rule. The analysis depends on the calculus of non-standard Mellin pseudodifferential operators and on some new estimates for the kernels of these operators. Calculations using piecewise constant and piecewise linear splines are reported. These are consistent with the theoretical results and suggest some further conjectures about the performance of this method.

J. GWINNER (Universität der Bundeswehr, München):

A boundary integral approach to unilateral problems of 4^{th} order

Up to now, in numerical analysis unilateral problems of 4^{th} order are only treated by finite element methods. On the other hand, following Duvaut and Lions, there are several different interesting unilateral problems for linear flat plates where the unilateral conditions are prescribed on the boundary. In this talk, we discuss an approach using a Green formula and the boundary layer potential operators to arrive at a minimization problem or an equivalent variational inequality that lives on the boundary only.

T. HARTMANN (Universität Hannover):

Interior error estimates for boundary integral equations on polygons

Even for smooth right-hand sides the solution of Symm's integral equation on a polygon Γ can be expected to be in Sobolev spaces $H^s(\Gamma)$, $s = -1/2 + s_0$, where s_0 depends on the angles of Γ and takes values between 1/2 and 1. However, for a smooth subsegment of a polygon away from the corners the solution is smooth for smooth data. We derive interior error estimates for the Galerkin solution using piecewise constant trial functions on quasiuniform meshes. The local error on subsegments can be estimated quasioptimally up to an additional term with the global error in a Sobolev norm $H^s(\Gamma)$ with $s << -1/2$. Thus, the local convergence of the Galerkin error is of higher order than the global convergence. These results are confirmed by numerical examples.

With these estimates local efficiency of a simple adaptive method can be shown. In order to derive these results, the interior error has to be estimated more precisely. This can be done by using a special kind of cut–off functions. We show that if an adaptive algorithm is constructed with the residual being equally distributed over the polygon, then the adaptive method is locally efficient, i.e., the mesh is not overrefined. Therefore we show that, locally, the error of the best approximation is of the same order as the residual. Since the error of the Galerkin solution cannot exceed the error of the best approximation, we obtain the desired result.

N. HEUER (Universität Bremen, Landesrechenzentrum):

Aspects on linear systems arising from the boundary element method

In general, the matrices of linear systems arising from the boundary element method (BEM) are fully occupied. However, usually many of the entries are very small. It is shown that the single layer operator applied to Legendre polynomials decreases rapidly for increasing polynomial degree and decreasing element size of the underlying mesh. This property results in an estimate of the matrix elements which is used a–priori to make the matrices sparse while retaining the convergence rate of the Galerkin scheme.

A second topic of this talk was the application of the additive Schwarz method to the BEM as a preconditioner. Two versions in obtaining a decomposition of the boundary element space in case of the single layer operator were discussed. For the decomposition based on the decomposition of the boundary, M. Hahne and E.P. Stephan obtained an upper bound for the condition number of the preconditioned linear system in case of the h–version of the BEM with piece–wise constant ansatz–functions. A second decomposition was introduced which divides the boundary element space with respect to the degrees. Therefore, the condition numbers are bounded for the h–version of the BEM with arbitrary, fixed degree.

Several numerical tests underlined the theoretical investigations.

<u>G.C. HSIAO</u> (University of Delaware, U.S.A), E. SCHNACK (Universität Karlsruhe) and W.L. WENDLAND (Universität Stuttgart):

A hybrid coupled finite–boundary element method for boundary value problems in elasticity

In this lecture, we present some error and stability analysis for the macro–element approach based on a hybrid–stress method with BEM for treating problems in solid mechanics with regions of high stress concentration. This approach is a variant of

the hybrid–element approach in the FEM with Trefftz elements. Here the Trefftz elements are modelled with potentials supported by the individual element boundaries. This defines the so–called macro–elements.
The most attractive feature of the present coupling procedure is to utilize a generalized compatibility condition wich allows to relax the continuity requirements for the boundary displacement field. In particular, the mesh points of the macro–elements can be chosen independently of the nodes of the finite element structure which allows to combine various independent meshes. Moreover, this method can also serve as the basic algorithm for employing preconditioned iterative solution schemes in domain decomposition.
Numerical implementation of the method has been successfully carried out for two– and three–dimensional problems by E. Schnack and his research group at Karlsruhe.

L. JENTSCH (Technische Universität Chemnitz–Zwickau):

On different boundary integral approaches for solving problems with interfaces

1. The main problem for solving boundary value problems for piece–wise homogeneous bodies with the boundary integral equation method (BIEM) consists in the fact that the transmission (contact) conditions on the interfaces include derivatives of different orders. The progress of the BIEM is connected with the state of the integral equations theory. Whereas in the beginning, only the theory of singular integral equations on closed manifolds was available, at present, the theory of pseudodifferential equations on manifolds without and with boundary permits the investigation of rather general non–classical mixed interface problems in the theory of elasticity of anisotropic bodies.
Useful are particular solutions (contact tensors) which satisfy the contact conditions. Potentials with the contact tensor in the kernel lead to singular integral equations with fixed singularities. Another representation formula, due to D. Natroshvili for the rigid contact problem (Problem C), can be applied for mixed contact problems if on one part S_1 of a closed surface S the contact conditions of Problem C and on the remaining part S_2, the contact conditions of sliding without friction (Problem G) or straddle conditions (Problem H) are to be satisfied. The problems C–H and C–G can be reduced to equations on S_2 with pseudodifferential operators of orders -1 and 1, respectively.

2. As a final procedure, the BIEM potentials must be calculated in the domain. In a neighbourhood of a corner point, the density of the potential has a typical asymptotic

expansion. For vectors of such an expansion, we consider the elastic potentials of the single and double layer type on an angle decomposition formula into the sum of a singular and regular part. If the singular exponent is a non-negative integer, explicit expressions for the potentials were found.

P. JUNGHANNS (Technische Universität Chemnitz-Zwickau):

Numerical analysis for nonlinear Cauchy-singular integral equations

Certain two-dimensional free boundary value problems can be investigated by transforming them to nonlinear Cauchy-singular integral equations of the form, e. g.

$$G(x,u(x)) = \frac{1}{\pi}\int_{-1}^{1}\frac{u(y)dy}{y-x} + d, \; -1 < x < 1, \; u(-1) = u(1) = 0\,,$$

or

$$u(x) = \frac{1}{\pi}\int_{-1}^{1}\frac{F(y,u(y))dy}{y-x} + f(x) + d + ex, \; -1 < x < 1, \; u(-1) = u(1) = 0\,.$$

$G(x,u)$, $F(x,u)$ and $f(x)$ are given real-valued functions, and we are looking for the unknown function $u(x)$ and the constants d and e.

For the numerical solution of such equations, we propose Newton projection methods. We seek the approximate solution to $u(x)$ in the form $u_n(x) = \sigma(x)v_n(x)$ where v_n is an algebraic polynomial of degree less than n and σ is a generalized Jacobi weight representing the asymptotics of the solution at the endpoints of the integration interval. Then, for example, the Newton collocation method consists of the discretizations of the original equation with the help of the Lagrange interpolation operator with respect to another appropriately chosen generalized Jacobi weight and solving the discrete equations by the Newton iteration method. To calculate the images of the ansatz-functions with respect to the singular integral operator accurately we apply the Gaussian quadrature rule with respect to the weight $\sigma(x)$. Considering only the modified Newton iteration method, we give convergence results (in weighted L^2-norms) in the following sense:

1. There exist suitable initial guesses such that the linearized equations in each Newton step are uniquely solvable for all sufficiently large n.
2. The solutions of these equations converge to a solution of the discrete (nonlinear) equation (for all sufficiently large, but fixed n).

3. The sequence of these solutions converges to the solution of the original problem as n tends to infinity.

As an example, we consider the free boundary value problem of free surface seepage from a channel underlain by a drain at a finite depth, which leads to an equation of the second type (see above). We discuss some computational aspects of the Newton collocation method and give numerical results.

REFERENCE:

Peter Junghanns: Numerical analysis of Newton projection methods for nonlinear singular integral equations, to appear in: *J. Comp. Appl. Math.*, 1994.

K. KALIK and W.L. WENDLAND (Universität Stuttgart):

On strong and hypersingular boundary integrals

Our aim is to find formulae for the numerical evaluation of singular and hypersingular integrals of the form

$$\text{p.f.} \int_S K(x;x^0)\varphi(x)dS$$

where $S \subset \mathbb{R}^3$ is a given C^k–surface, $k \geq 1$, $x^0 \in S$, $K(x;x^0) = O\left(\frac{1}{|x-x^0|^m}\right)$, $2 \leq m \in \mathbb{N}$. The symbol p.f. in front of the integral stands for Hadamard's partie finie integral.

Using appropriate local coordinates one gets the representation

$$\text{p.f.} \int_\Sigma K(x;x^0)\varphi(x)d\Sigma = \text{p.f.} \int_\Omega v(y)\mu(y)dy$$

where $\Sigma \in S$ defines an open neighbourhood about x^0 and Ω the projection of Σ in the coordinate plane with variables $y = (y_1, y_2)$.

Let

$$v(y) = \frac{k(y)}{r^m} = \frac{k_0(0) + k_1(y) + \ldots + k_{m-2}(y) + k^{[m-1]}(y)}{r^m}$$

where $k(y) = k(0)+\ldots+k_{m-2}(y)+k^{[m-1]}(y)$ is the Taylor formula with the remainder $k^{[m-1]}(y)$ and $r \doteq \sqrt{y_1^2+y_2^2}$. Accordingly, we find

$$\text{p.f.} \int_\Omega v(y)\mu(y)dy = \sum_{q=0}^{m-2} \text{p.f.} \int_\Omega \frac{k_q(y)}{r^m}\mu(y)dy$$

where $k_q(y)$ is a homegeneous polynomial of degree q.
We show the following explicit formula:

$$\text{p.f.} \int\limits_{\Omega} \frac{k_q(y)}{\rho^m}\mu(y)dy = \int\limits_{\Omega} \frac{k_q(y)}{r^m}[\mu(y) - \mu(0) - \ldots - \mu_{m-q-1}(y)]dy + \sum_{|\alpha|\leq m-q-1} \frac{c_\alpha D^\alpha \mu(0)}{q-m+|\alpha|+2},$$

with

$$c_\alpha = \int\limits_{r=1} y^\alpha \cdot k_q(y) \cdot \sum_{j=1}^{2} y_j \cos(n, y_j) d\sigma .$$

B.N. KHOROMSKIJ (JINR Dubna, Russia) and G. SCHMIDT (WIAS Berlin):

Fast interface solvers for biharmonic Dirichlet problem on polygonal domains

We propose and analyze efficient discretization schemes for boundary and interface reductions of the biharmonic problem on polygonal domains. We study mapping properties of Poincaré–Steklov (P.S.) operators as well as single– and double–layer potentials. We propose asymptotically optimal mixed FE discretizations of the Schur complements to P.S. operators which admit efficient matrix compression and implementation with the complexity $n \log^2 n \log \varepsilon^{-1}$ for step–type boundaries, where n is the number of degrees of freedom on the underlying boundary and $\varepsilon > 0$ is the required accuracy. As a consequence, an asymptotically optimal interface solver for the clamped plate boundary value problem on polygonal domains is derived. The numerical experiments presented confirm the theory.

B. KLEEMANN (WIAS Berlin):

Wavelet algorithm for the exterior Dirichlet problem of the Helmholtz equation

The talk presents intermediate results of the joint work with U. Dahmen, S. Prößdorf and R. Schneider to this topic. The treatment of the scattering of time–harmonic acoustic and electromagnetic waves leads to an exterior boundary value problem for the Helmholtz equation. We consider objects in $\mathbb{R}^2$ with smooth boundary and assume a real wave number k. Furthermore, we only treat the case of "soft–sound" scattering which corresponds to Dirichlet boundary conditions.

For the arising boundary integral equation of the first kind we present a fully discrete wavelet method. The unknown density we search as a piecewise linear function. Additionally, we consider a collocation method using quadrature for the integration. For an appropriate treatment of the logarithmic singularity of the kernel function we use a graded mesh with grading in the vicinity of the singularity. To get a matrix in semi-wavelet representation we use a transformation which maps a wavelet basis to a basis of the finite scale. Additionally, for the collocation side we apply Brand/Lubrecht functionals getting a matrix in wavelet representation. During the direct calculation of the matrix entries in the wavelet representation, an a-priori compression criterion is applied, getting a sparse matrix. Because of the bad behaviour of the integral operator, we propose a preconditioner to reduce the number of iterations for the GMRES iterative linear system solver. At the end, the solution is transformed back from the wavelet basis to a usual basis on the fine scale with a fast pyramid type transformation. The resulting solution has the same order of convergence as a corresponding single scale approach with n^2 matrix entries. These good results are obtained for wave numbers k not greater than 10.

R. KRESS (Universität Göttingen):

Integral equation methods in inverse obstacle scattering

The inverse problem we consider is to determine the shape of an obstacle from a knowledge of the far field pattern for the scattering of incident time-harmonic acoustic (or electromagnetic) plane waves. It occurs in a variety of applications and is difficult to solve since it is nonlinear and improperly posed. In this survey, we shall describe two integral equation methods for the approximate numerical solution of the inverse obstacle scattering problem in the resonance region. In particular, for the theoretical foundation of a Newton method, Frèchet differentiability with respect to the boundary is established for the far field operator, which for a fixed incident wave maps the boundary curve onto the far field pattern of the scattered wave. The numerical implementation of the Newton method via boundary integral equations is described. By a numerical example it is illustrated that the method yields satisfactory reconstructions.

G. KUHN und A. FOERSTER (Universität Erlangen-Nürnberg):

A FBEM-formulation for hyperelastic and elastoplastic problems at finite strains

A novel formulation of a Field-Boundary-Element-Method (FBEM) for hyperelasticity and elastoplasticity at finite strains is presented. The proposed formulation uses a Total–Lagrange scheme. Therefore, the system matrices have to be generated only once. The constitutive model used is based on the concept of an intermediate configuration. This enables to split the constitutive equations into a time–independent hyperelastic relation relative to the intermediate configuration and into more complex evolution equations for the intermediate configuration and for further internal variables. For the derivation of the boundary integral equation only the time–independent hyperelastic relation for the stress tensor is needed. Consequently, the basic boundary integral equation itself is time–independent and does not depend on the explicit structure of the evolution equations. The proposed formulation finally provides a nonlinear set of equations with identical structure, for both boundary and internal nodes, for which a consistent linearisation can be derived. The basic unknowns are the displacement gradients.

U. LANGER (Johannes–Kepler–Universität Linz, Österrreich):

Parallel solvers for linear and nonlinear coupled boundary elment– finite element–equations

The BEM is advantageous in many applications, in particular, the mathematical models become easier to handle in case of the necessity of far–field computations and of approximations of singularities. Especially in magnetic field computations, the coupling of the BEM with the FEM can be quite useful.

The non–overlapping domain decomposition is an important tool for formulating adequate mathematical models as well as for their discretization and their parallel solution.

The author presents parallel algorithms for solving BE–, FE– and coupled BE–FE–equations approximating linear and non–linear plane magnetic field problems in bounded and unbounded regions. The methods are of $O(N)$, or at least, $O(N \lg \lg N)$ algebraic complexity and of high parallel efficiency. Finally, the author discusses some numerical results obtained by the code FEM ⊕ BEM on various massively parallel machines with up to 128 processors.

R.C. MAC CAMY (Carnegie Mellon University Pittsburgh, U.S.A.):

Approximate boundary conditions for two–dimensional wave equations

This talk represents joint work with J. Bielak, T. Hagstrom and S. Harriharan. It concerns the solution of scattering problems for the two–dimensional wave equation using appropriate boundary conditions on artificial boundaries. These conditions are approximations to exact conditions which are temporally and spatially non–local.

They are determined by a combination of geometrical optics and low frequency analysis. They are designed to capture the dissipation properties. The model problem of a circular cylinder is studied in detail with error estimates established and numerical examples presented.

M. MAISCHAK and E.P. STEPHAN (Universität Hannover):

The h–p version of the BEM in 3D with geometric mesh

The pure h– and p–versions of the boundary element method converge on polyhedral surfaces only algebraically to the presence of corner, corner–edge and edge singularities. We show that these singularities can be compensated by using splines with linearly increasing polynomial degrees on a geometric mesh which is refined toward edges and corners. In this way, we obtain exponentially fast convergence of the Galerkin solution for the weakly singular integral equation of the first kind with the single layer potential for the Laplacian. This result is derived by showing that all the singularity terms of the solution belong to countably normed spaces with appropriate weight functions if the given data are piecewise analytic.

Furthermore, corresponding results are given for the Neumann problem, the Lamé equation and the Helmholtz equation together with numerical experiments which show the exponential convergence of the $h-p$ version of the BEM Galerkin schemes.

P.A. MARTIN (University of Manchester, Manchester, U.K.):

Expansion methods for two–dimensional hypersingular integral equations

The two–dimensional problem of acoustic scattering by a hard, curved strip can be reduced to a one–dimensional hypersingular integral equation over an interval. An effective method for solving this equation is: expand the unknown function as a series of Chebyshev polynomials if the second kind with a square–root weight, and then determine the coefficients by collocation.

What happens for three–dimensional problems, where the scatterer is a flat, hard plate Ω? A hypersingular integral equation over Ω is easily derived. When Ω is a circular disc, say D, we derive an expansion–collocation method; our expansion involves products of trigonometric functions in the azimuthal direction and Gegenbauer polynomials in the radial direction (S. Krenk, 1979). This method for two–dimensional hypersingular integral equations over discs is completely analoguous to that for one–dimensional hypersingular integral equations over intervals.

If Ω is not circular, we proceed by mapping Ω onto a disc D, and then use the above expansion–collocation method. However, in order to preserve the structure of the kernel, we must use a conformal mapping. This observation has many implications, most of which remain to be explored. Some applications to crack problems, such as those where Ω is almost circular, were described.

S.E. MIKHAILOV (University STANKIN, Moscow, Russia):

Plane boundary value problems and boundary integral equations for an elastic body with thin elastic reinforcements

First, the boundary value problem is formulated for a two-dimensional body reinforced by one-dimensional stringers. The stringer-induced terms in the boundary conditions of the problem are expressed by Volterra integral operators. Then existence and uniqueness theorems are obtained. Moreover, the asymptotics of displacements and stresses near to the singular points are investigated. The leading singular terms of these asymptotics do not depend on the stringer properties for the considered curvilinear beam model of the stringer; and they are the same as for the problem with infinitely rigid stringers of described displacements.

The plane problem for an elastically bordered multi-connected body is reduced to two different indirect boundary integral equations of the second kind. Spectral properties of these equations are obtained and finite-dimensional integral operators as perturbations are given to obtain unconditionally and uniquely solvable integral equations. Also, the asymptotics of the integral equations solutions are explored.

One of the boundary integral equations considered was reduced to a system of linear algebraic equations by using the boundary element method and collocation. A singular approximation of the integral equation solution was used within elements which include singular points. Corresponding computer programs were designed and some numerical calculations were executed.

REFERENCES:

1. Mikhailov, S.E. and Namestnikova, I.V.: Boundary value problems of elasticity theory for plane domains with one-dimensioal elastic reinforcements, *Journal of Applied Mechanics and Technical Physics (PMTP)*, **1**,1991, pp. 98–108.
2. Mikhailov, S.E.: Some boundary integral equations of plane elasticity problems for non-simply-connected bodies with one-dimensioal elastic borders and corner points, *Mech. of Solids (Izv. AN SSSR. MTT)*, **27**, No. 1, 1992, pp. 36–47.
3. Mikhailov, S.E.: Asymptotic behavior of the solutions of some integral equations and plane problems of elasticity near angular corners with displacements

specified on the boundary, *Mech. of Solids (Izv. AN SSSR. MTT)*, **26**, No. 2, 1991, pp. 28–40.

L. MORINO (Third University of Rome, Italy):

Aerodynamics and aeroacoustics of rotors

A review of the use of boundary integral equations in aerodynamics and aeroacoustics has been presented, with the objective of addressing what has been accomplished and, even more important, what remains to be done. The presentation emphasized aerodynamics and aeroacoustics of the aeronautical type (i.e. wings, propellers, and helicopter rotors), for which the issue of the wake is essential (indeed, for steady incompressible potential flows there exist no lift and no drag, according to the well known d'Alembert paradox).

A general formulation for unsteady potential flows has been presented; both incompressible and compressible flows have been considered (for a more complete review which includes viscous flows, the reader is referred to Ref. 1). Special attention was given to how to formulate the problem of potential flows, in particular, to the issue of the existence of the wake (a surface of discontinuity for the velocity potential, fully equivalent to a vortex layer, which allows one to circumvent the d'Alembert paradox). Thus, the issue of the boundary conditions on the wake and on the trailing edge have been addressed in some detail (some unresolved issues related to the impulsive start have been pointed out).

Next, the derivation and the interpretation of the boundary integral equations have been examined. In particular, it was shown how the treatment of the wake is particularly simple within BIE framework. Also, it was shown how the formulation for compressible flows reduces to that for the scalar wave equation for a surface that moves with respect to the medium and yields an integral representation for the potential which is closely related to the Kirchhoff formula for the wave equation (retarded potential with time delays related to the signal propagation at the undisturbed speed sound). Furthermore, it was indicated how in the transonic range the nonlinear terms are important and yield a volume distribution of sources in the integral representation for the potential (with intensity also delayed).

Issues related to the discretization (i.e. panel methods, boundary element methods) have been barely addresed; the nature of the unsteady–flow algorithm (a time marching technique, related to the retarded–potential formuation) was discussed. Finally, recently obtained numerical results (see Ref.2) for aerodynamics and aeroacoustics in the transonic range, have been presented, which demonstrate the efficiency and accuracy of the methodology. In particular, it was shown how the time marching technique may be used even to find the steady state solution and may yield convergence (to machine accuracy) in only ten iterations.

REFERENCES.

1. L. Morino: Boundary integral equations in aerodynamics. *Applied Mechanics Reviews*, **46**, N°8, August 1993, pp. 445–466.

2. M. Gennaretti, M. Iemma and L. Morino: A boundary integral method for unified analysis of aerodynamics and aeroacoustics analysis of hovering rotors. AGARD Conference on Aerodynamics and Aeoracoustics of Rotors, Berlin, October 1994.

D. NATROSHVILI (Technical University Tbilisi, Georgia):

Boundary integral equation methods in steady state oscillation problems for anisotropic bodies

The investigation deals with the steady state oscillation problems for homogeneous and piece–wise homogeneous elastic bodies with interior cuts of arbitrary shape. The case of interface cracks is considered, too.

These boundary value problems are studied by the potential method. The original problems are reduced to pseudodifferential equations on manifolds with boundary. The main results of the investigation are:

1. The generalization of the Sommerfeld–Kupradze radiation conditions to the anisotropic case and uniqueness theorems.
2. The establishment of the regularity of solutions near singular points and edges.

S.A. NAZAROV and I.I. ARGATOV (St.–Petersburg, Russia):

Ill–posedness of integral equations in the asymptotic theory of thin punches

The asymptotic theory of thin punches can be obtained by the application of the method of matched asymptotic expansions. When sending the thickness ε of the punch's plane base Γ_ε to zero we replace asymptotically the two–dimensional domain Γ_ε by the contour Γ_0 while the forces loading Γ_ε are changed to concentrated forces distributed along Γ_0 with some unknown density γ. The asymptotic analysis of this procedure gives an integral equation for determining γ or an variational inequality in the case of the Signorini problem. The corresponding integral operator J is a pseudo–differential operator with the principal symbol $c \ln |\xi|$, therefore, the above–mentioned limit problems still contain the large parameter $|\ln \varepsilon|$. These facts imply the following properties:

1. The approximate solution γ of the equation can be obtained in the form of a series in powers of $|\ln\varepsilon|^{-1}$;
2. there exists a sequence $\varepsilon_k \downarrow +0$ such that the equation with $\varepsilon = \varepsilon_k$ has no solution (ill-posedness of equations); however, the procedure developed by M. Fedoryuk (1980) gives an approximate solution which produces the discrepancy $O(\varepsilon)$ in the equation;
3. the "logarithmic" asymptotics of solutions of the variational inequality are available while in each step of the asymptotic procedure the asymptotic description of the contact zone must be found.

S. PRÖSSDORF (WIAS Berlin):

The qualocation method for Symm's integral equation on a polygon

Here we discuss the convergence of the qualocation method for the integral equation of the first kind with logarithmic kernel on closed polygonal boundaries in $\mathbb{R}^2$. Qualocation is a Petrov–Galerkin method in which the outer integrals are performed numerically by special quadratur rules. Before discretization, a nonlinear parametrization of the polygon is introduced which varies more slowly than the arc–length near each corner and leads to a transformed integral equation with a regular solution. We prove that the qualocation method using smoothest splines of any order k on a uniform mesh (with respect to the new parameter) converges with optimal order $O(h^k)$ (with respect to the L_2– resp. weighted L_2–norm). Furthermore, the method is shown to produce superconvergent approximation to linear functionals, retaining the same high convergence rates as based on a recent joint work with J. Elschner and I.H. Sloan. (Preprint No. 119, WIAS Berlin 1994).

S. RJASANOW (Universität Kaiserslautern) and M.PESTER (Technische Universität Chemnitz–Zwickau):

A parallel realization of the panel method in 3D

We consider a numerical solution of the three-dimensional Dirichlet boundary value problem for the Laplacian by using the panel method. This method leads to an algebraic system of linear equations with a full, dense, large order and, in general, nonsymmetric matrix. Fortunately, there are some special classes of three–dimensional domains leading to matrices consisting of so–called circulant–block matrices (rotational domains). The solution of a system of linear equations, involving a circulant–block matrix, consists of an $O(N^2)$ amount of preparation work independent of the right–hand side of the system, and of the solution itself leading to

$O(N^{3/2} \ln N)$ arithmetical operations. We show that the preconditioning, based on the algorithms with circulant-block matrices, fullfills all requirements for the efficient parallel procedure; and can be used together with some iterative schemes, e. g. the usual Gradient method or the modern BiCGSTAB method, for the numerical solution of the BEM systems.

A.-M. SÄNDIG (Universität Stuttgart):

Boundary integral equations for coupled structures in solid mechanics
Existence, uniqueness and reguarity of solutions of linear elastic two– and three–dimensional boundary–interface problems are investigated. The domains consist of two different non–smooth anisotropic media, where several boundary conditions and standard coupling conditions are given.
In order to derive boundary integral equations which lead to efficient computational algorithms we are interested in the following aspects:

1. We study appropriate extensions of the boundary data onto the interfaces.
2. We construct appropriate extensions of the coupling conditions onto the boundary pieces.

These methods yield "local" pseudodifferential equation systems with corresponding Steklov–Poincaré operators on the interfaces or on the boundary pieces, respectively. The regularity of the solutions is strongly influenced by the different media properties and the corners and edges of the domains which is demonstrated by different examples. Using the Maz'ya–Plamenevsky functionals we derive explicit formulae for 2D stress intensity factors.

J. SARANEN (University Oulu, Finland):

Collocation solution of the single layer heat equation
We consider a boundary element method for the single layer heat equation. As trial functions we use the tensor products of continuous piecewise linear splines with collocation at the nodal points. The spatial domain is any bounded domain with a smooth boundary in $\mathbb{R}^2$. For the method we use arclength representation of the curve. Convergence and stability results are shown as well as some numerical experiments.

G. SCHMIDT (WIAS Berlin):

Boundary integral operators for the bi–Laplacian in domains with curves
Interior and exterior Dirichlet problems for the biharmonic equation are studied by using integral equation methods. Based on the representation of H^2–solutions as potentials of the Cauchy data, a strongly elliptic system of integral equations on the non–smooth boundary of the domain is obtained. If the exterior homogeneous Dirichlet problem has only the trivial solution, this system is uniquely solvable and various approximation methods converge. We study properties of the Steklov–Poincaré operators for the interior and the exterior problem, respectively, from their representations as integral operators.

R. SCHNEIDER (Technische Hochschule Darmstadt):

Multiscale and wavelet methods for boundary integral equations
The talk presents results of joint work with W. Dahmen, B. Kleemann, T. v.Petersdorff, S. Prößdorf and C. Schwab.
Discretizing the Galerkin or collocation method for solving boundary integral equations by means of a wavelet– or multiscale–basis gives numerically sparse matrices. Depending on the basic properties of the biorthogonal multiscale basis, namely regularity, approximation order and vanishing moments, we propose a "compression" of these matrices by deleting certain entries in a way we do not compromise or disturb the optimal convergence rate of the original scheme. The compressed matrices are shown to have at most $O(N_j \log^\alpha N_j)$, or optimally $O(N_j)$, nonzero entries, where N_j denotes the number of unknowns. We propose a diagonal preconditioning and obtain an approximate solution by an iteration method within a complexity of $O(N_j \log^\alpha N_j)$ or $O(N_j)$ arithmetric operations. A fully discrete method was proposed based on a composite quadrature method.

C. SCHWAB (University of Maryland, Baltimore County, U.S.A.):

Convergence analysis of a multiwavelet discretization of 2nd kind boundary integral equations on arbitrary surfaces in $\mathbb{R}^3$
We consider a Galerkin method for an elliptic pseudodifferential operator of order zero. We use piecewise linear discontinuous trial functions on a triangular mesh and describe an orthogonal wavelet basis. Using this basis, we can compress the stiffness matrix from N^2 to $O(N \log N)$ nonzero entries and still obtain (up to $(\log N)$ terms) the same convergence rates as for the exact Galerkin method.
This is joint work with T. von Petersdorff and R. Schneider.

I.H. SLOAN (University of New South Wales, Sydney, Australia):

Qualocation with an irregular mesh for Symm's integral equation on Lipschitz curves

This talk describes joint work with K.E. Atkinson on the two-dimensional single-layer equation for a region with a Lipschitz boundary Γ. It is well known that (provided cap $\Gamma \neq 1$) the Galerkin method with piecewise constant trial space is stable, no matter how the mesh is chosen. On the other hand, there is as yet no stability proof for the piecewise-constant collocation method (with collocation at the midpoints of subintervals) for general curves and general meshes. The qualocation, or semidiscrete Galerkin method replaces the outer integral in the Galerkin method by a composite quadrature rule obtained by using a simple version of a fixed m-point rule q on each subinterval of the mesh; the collocation method is recovered if q is the simple mid-point rule.

In this talk it is shown that the qualocation method is stable and optimally convergent in appropriate norms, provided that q has a small enough Peano constant, assuming only quasi-uniformity of the mesh.

W. SPANN (Universität München):

Error estimates for the boundary element approximation of a semi-coercive Signorini problem in elasticity

The two-dimensional contact problem of linear isotropic elasticity can be written as the variational inequality $a(u, v-u) \geq f(v-u)$ $(v \in K)$ where K is defined as the subset of $H^1(\Omega)^2$ satisfying the non-penetration condition $v_2(x) + x_2 \geq 0\,(x \in \partial\Omega)$ and $\int_{\partial\Omega} v_1 ds = 0$. Due to the semi-coercive character of this problem, additional compatibility conditions have to be satisfied in order to obtain existence and uniqueness of solution. The problem is rewritten as a boundary variational inequality using the Poincaré-Steklov operator; and approximated by linear boundary elements. We use a discrete Poincaré-Steklov operator that is composed of Galerkin approximations of the underlying single and double layer potentials. It is modified by multiplying the identity by $1 + \beta h^3\,(\beta > 0)$ to obtain a positive definite operator implying the unique solvability of the discrete boundary variational inequality.

Requiring the non-penetration condition pointwise on the grid quasi-optimal error estimates are obtained using an abstract error estimate due to the author, especially tailored to semi-coercive problems. It is proven that the hypotheses of that theorem depend on the location of the central axis of forces and are satisfied for sufficiently regular solutions.

O. STEINBACH (Universität Stuttgart):

Preconditioned iterative solvers for boundary element and domain decomposition methods

The iterative solution of linear systems resulting from a boundary element discretization of an elliptic boundary value problem requires the use of a good preconditioner to keep the number of iterations constant. We will propose a general technique independent of the mesh and of the degree of the trial functions used. Moreover, such a preconditioner is needed in domain decomposition methods, too.
We will give a brief survey of these methods based on both representations of the Steklov–Poincaré operator by boundary integral operators. The resulting algorithms can be characterized as Schur complement iterations and as transformations of the original system like the Bramble/Pasciak transformation of a skew–symmetric, but positive definite system into a symmetric and positive definite one.
Finally, we discuss different preconditioners for these methods.

E.P. STEPHAN (Universität Hannover):

Fast solvers for integral equations of the first kind

Multigrid methods and multilevel preconditioners for boundary element discretizations (with the h–version) of first kind integral equations with weakly and hypersingular kernels are discussed. We find that the number of iterations needed is bounded or grows not worse than logarithmically in the number of unknowns. Especially for the hypersingular integral equation, the multilevel–additive Schwarz method yields an efficient preconditioner for the conjugate gradient method. Furthermore, we propose and analyze a fast iterative solver for symmetric and indefinite coupled finite element/boundary element problems. The method is based on multigrid preconditioning of seperate positive definite and negative definite parts of the coupled scheme (which arise from a differential and an integral operator, respectively) and minimum–residual–iteration on the resulting preconditioned indefinite system. No Schur complement is required. The obtained solver is nearly optimal, i.e. the number of iterations grows only slowly with the problem size.

M. SURI (University of Maryland, Baltimore County, U.S.A.):

The optimal p–version approximation of singularities on polyhedra in the BEM

We consider elliptic boundary value problems on three–dimensional polyhedral domains. We describe the three types of singular components that arise in the solution:

edge, vertex, and edge–vertex singularities. We analyze the approximation of the traces of each of these different types of singularities by polynomial subspaces on the boundary as the polynomial degree p tends to infinity (the p–version). We establish asymptotic rates of convergence that are optimal in the H^t norm over the boundary for $0 \leq t \leq 1$. We apply these results to a Galerkin boundary element method (BEM) formulation for a model Neumann problem, obtaining the optimal convergence rate for the p–version BEM over polyhedral domains. This is joint work with C. Schwab.

E.E. TYRTYSHNIKOV (Russian Academy of Sciences, Moscow):

Block Toeplitz–based and block circulant–based solution strategies
We discuss a purely algebraic approach to the solution of linear systems with large dense coefficient matrices arising when a projection method is applied to solve a pseudodifferential equation. We show, numerically and theoretically, that block circulant matrices appear to be rather good preconditioners providing a significant acceleration of basic iteration schemes, for example, the GMRES. We also present a sketch of a theory of spectral distributions which explains why block circulants are that good in the rôle of preconditioners.

V. VORONIN (Sibirian Div. Russian Acad. Sciences, Novosibirsk):

On the foundation of collocation methods for weakly singular equations
Equations of the 1st kind with logarithmic and weak degree singularity in the kernels are considered on both closed and unclosed curves. Three approaches to the foundation of collocation methods are presented. The first ("continuous") approach uses the known eigenfunctions for the principal part of an integral operator and gives estimates for the error and residual in Hölder norms all over the curve. The second ("discrete") approach is based on properties of circulant and Toeplitz matrices and gives estimates of the condition numbers of corresponding discretized algebraic systems for logarithmic and weak degree kernels on closed and unclosed curves. The third ("convex") approach is now developed and is based only on convexity properties of images of the basic functions. Some suggestions are made concerning the extension of proofs to 2D integral equations on arbitrary surfaces.

W.L. WENDLAND (Universität Stuttgart) and C. SCHWAB (University of Maryland, Baltimore County, U.S.A.):

On the extraction technique in boundary integral equations

In this paper we develop and analyze a bootstrapping algorithm for the extraction of potentials and arbitrary derivatives of the Cauchy data of regular three-dimensional second order elliptic boundary value problems in connection with corresponding boundary integral equations of the so-called first kind. The method rests on the derivatives of the generalized Green's representation formula which are expressed in terms of singular boundary integrals as Hadamard's finite parts. Their regularization together with asymptotic pseudohomogeneous kernel expansions yields a constructive method for obtaining generalized jump relations. These expansions are obtained via composition of Taylor expansions of the local surface representation, the density functions, differential operators and the fundamental solution of the original problem, together with the use of local polar coordinates in the parametric domain. For piece-wise polynomial surface approximation and explicitly given fundamental solution, the corresponding expansion terms can be computed automatically by symbolic manipulation. The output is used for applying appropriate numerical integration procedures to weakly singular integrals after regularization. For boundary integral equations obtained by the direct method, this method allows the recursive numerical extraction of potentials and their derivatives near and up to the boundary surface.

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