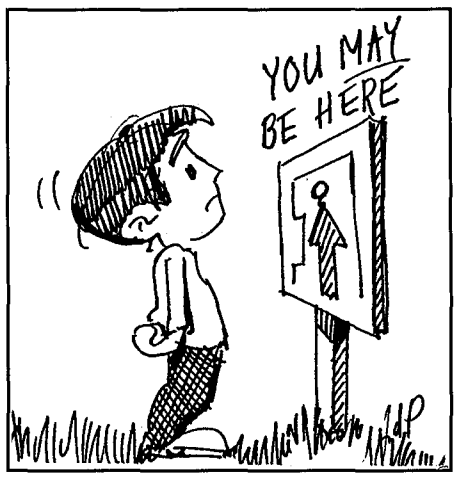
Householder XI Continues the Gatlinburg Tradition

By John de Pillis

During the week of June 18, 1990, the Eleventh Householder Symposium on Numerical Algebra took place at the Nya Hotel Tylosand, on the west coast of Sweden, near the town of Halmstad. The approximately 150 attendees were a truly international group, with a large contingent from the Soviet Union and Eastern Europe—a first for these meetings.

Some participants arrived on Sunday, June 17, to register and settle in early. Friends old and new made contact, and various groups set out in search of local restaurants to share some time and their first meal in Halmstad. Recovery time was required for some victims of price-shock.

In certain respects, the casual visitor might conclude that the charming Nya Tylosand is not so much a hotel as an intelligence test. This impression was due, in part, to the numbering system of the rooms (for which no algorithm seems to exist) and to the helpful signs "HISS" and "RUM" ("elevators" and "room.")



Formal Talks

There were so many interesting lectures (often in conflict) that it would be impossible to give more than a fleeting impression of the meeting in this space. The rich and stimulating sessions showed the growing use of numerical linear algebra in an ever-widening range of applications. The many young persons in attendance provided further evidence of a stronger interest in the field than ever before.

The conference opened on Monday, June 18, with welcoming remarks from organizing committee chair Åke Bjorck. Gene Golub, extending Bjorck's greetings, mentioned that of the original organizers of the Householder (formerly called Gatlinburg) conferences, only David Young and Golub himself had attended every meeting. Velvel Kahan had also attended the very first meeting, held in Gatlinburg in 1961.

In the opening talk, James Demmel described some of his work on LAPACK, a sparse matrix library being designed for accuracy and portability, qualities that are not easy to realize on Cray computers! (See the "Informal Talks" section for a Cray test you can do at home.) Using component-wise relative error (as opposed to the more standard relative norm bounds), Demmel was able to achieve tighter error bounds in, for example, the solution of linear systems, generalized singular value decomposition, and the symmetric eigenvalue problem. The morning continued with Kahan's talk on symmetric rank-1 perturbed diagonal systems, along with some observations on the arithmetic weaknesses of the Crays.

K. Veselic gave more details on the accuracy of the one-sided Jacobi method as applied to $L'L = A$, in comparison with the use of the QR algorithm. The error bounds were elementwise, as described by Demmel, and were convincing enough to make Jacobi the method of choice for the LAPACK project.

Nicholas Higham talked about fast matrix multiplication, describing recent developments based on Strassen's algorithm (look for Higham's discussion of the practical use of fast matrix multipliers in an upcoming issue of *SIAM News*). The "usual" matrix multiplication involves an n^2 error term. In Strassen's method, the error exponent p for n^p ranges from 2 to 3.85, and the numerical error can be 10 to 100 times greater than that for standard multiplication.

Both IBM and Cray use Strassen's method in their libraries. Roger Grimes pointed out that Strassen's method requires more memory and so cannot be implemented in the level 3 BLAS (Basic Linear Algebra Subprograms) as a default. Kahan noted that the BLAS3 perform well with scaling but that Strassen's method does not.

Mario Arioli gave examples in which the use of a QR factorization to solve nonsingular systems resulted in errors much larger (up to 15 orders of magnitude) than did LU. His explanation was an error analysis that accounts for the

sparsity pattern of each Q_i (again, c.f. Demmel's talk). Normally, QR perturbs the entire upper triangle of A, not just the nonzero parts. Arioli also showed that QR cannot capture Skeel's error bounds for LU, but that it does yield the classical condition number.

Christian Bischof and Robert Plemmons both gave talks about condition estimators. Bischof discussed the application of his incremental condition estimator (ICE) in the context of sparse orthogonal factorization. Plemmons surveyed the work he has done with Dan Pierce, Gene Golub, and William Ferng on adaptive condition estimators (ACE and ALE) and their application to recursive least squares computations in signal processing.

New approaches for the iterative solution of nonsymmetric systems were the focus of three interesting plenary talks. In the first, Roland Freund suggested that use of his quasiminimal residuals (QMR) algorithm can be extended beyond the complex symmetric case. Unfortunately, it seems that QMR can fail in the same cases in which incurable breakdowns occur in the Lanczos algorithm.

Henk Van der Vorst then presented the stabilized conjugate gradient scheme (CGS) and suggested that it might be combined with QMR. The basic idea is that in biconjugate gradients, a polynomial P_i is created such that $P_i(A)$ reduces r_0 to r_i, and $P_i(A^T)$ reduces r'_0 to r'_i. CGS uses $(r_i, r'_i) = (P_i(A)P_i(A)r_0, r'_0)$ to get a recursion for r_i with no need for r'_i. The polynomial P_i is effectively squared, however, so that any conditioning problems with P_i are exacerbated. Van der Vorst also noted that $P_i(A)r_0$ is orthogonal to $Q_{i-1}A^Tr'_0$ for any polynomial Q of degree less than i. He recommends using $Q_i(A) = (I - \alpha_i A)^*(I - \alpha_1 A)(I - \alpha_0 A)$, with the parameters α_i chosen to minimize the norm of r_i. The resulting CGSTAB algorithm has a smooth convergence of residual norms and better performance than GMRES(k) or CGS; it has never broken down on device simulation problems.

Finally, Lothar Reichel presented a hybrid method that combines Richardson's method and GMRES(k). Reichel proposed that GMRES(k) be used to find the parameters for a Richardson iteration, with Leja points used to order the parameters. His approach for finding the parameters seems to differ from that used by Saylor, Smolarski (the pronunciation of which is left to the reader's discretion), Saad, and Elman—instead of using the underlying Arnoldi iteration, he uses the GMRES residual polynomial directly. He suggests that the new method has better properties because the GMRES residual polynomial captures the ε-pseudo spectrum (defined by Trefethen), while the Arnoldi approach does not.

Olof Widlund showed results from SESAM, a large finite element code for elasticity problems. He proposed eliminating interior nodes, that is, explicitly forming the Schur complement. He then tested three block preconditioners, based on the use of a coarse grid, the edge space of leftover unknowns, and the vertex space of leftover unknowns. The last choice provided the best preconditioner by far.

Kahan asked about nonlinear problems, where

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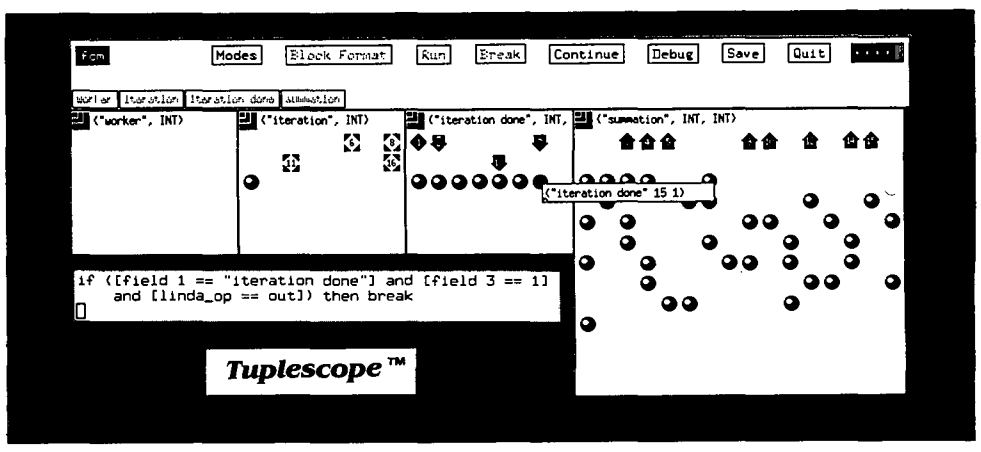

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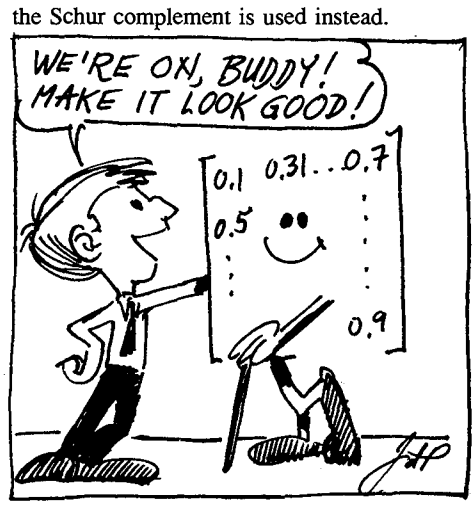
structural failure usually begins in the local elements (which are eliminated by Widlund's scheme) and then work their way up to larger structures. Widlund had no answer, having tested only linear problems. Roger Grimes mentioned that this approach is too expensive for three-dimensional problems, since what is left over consists of planes, not lines. Tony Chan bounced around in his chair at this comment but did not have a chance to respond until the next break. I did not hear his response, but apparently he considers the approach practical even for three-dimensional problems and has written something to that effect.

A. Yu Yeremin also proposed explicitly forming the Schur complement for elasticity problems, in spite of the additional storage and the large number of operations required. He suggested using an incomplete BSSOR-CG scheme as preconditioner-solver pair, unlike his previous work, in which he used a complete BSSOR preconditioner. The incomplete BSSOR is based on the use of an incomplete Cholesky factorization of the diagonal blocks of the matrix, rather than the complete factorization.

In the following talk, L. Yu Kolotilina discussed the use of direct approximations to the inverse of the matrix as preconditioners and presented a method for obtaining a symmetric approximation when A is symmetric and positive definite. When applied to elasticity problems, the preconditioned system has a larger condition number than the unpreconditioned system! However, significant improvement over BSSOR-CG and IBSSOR-CG is achieved when the Schur complement is used instead.



Only a few of the many other excellent talks given at the conference can be mentioned here. Certainly worth mentioning was Angelika Bunse-Gertner's talk on computing the eigendecomposition of unitary matrices; Bunse-Gertner showed that application of the QR algorithm to the Schur parameter form of a unitary matrix, and not to the unitary matrix itself, makes it possible to take advantage of many more of the zeros that occur for free during the bulge-chasing sequence.

Sabine Van Huffel gave an excellent overview and introduction to total least squares, providing motivation, basic analysis, and guidelines as to when total least squares should and should not be used (the alternative is regular least squares). Per-Åke Wedin, in an overview of perturbational analysis of linear and nonlinear least squares problems, advocated the use of iterative refinement for such problems. His analysis showed essentially that the dependence on the square of the condition number can be removed by this approach.

As always, much of the action at the Householder Conference took place in special sessions. One especially notable special session dealt with row projection methods. A. Dax of the Hydrological Service in Israel discussed the application of Kaczmarz methods for solving l_∞, l_1, and linear programming problems by a regularization approach. M. Neumann refined his analysis of the convergence of chaotic iterations, and Mario Arioli presented further results for the application of Cimmino's method to sparse nonsingular systems.

The Householder Prize

The Householder Prize, given in recognition of outstanding PhD dissertations in numerical analysis/algebra, was awarded jointly to Alan Edelman (PhD, MIT; adviser, Nicholas Trefethen) and Maria Beth Ong (PhD, University of Washington; adviser, Loyce Adams).

At the Thursday night banquet, Pete Stewart formally announced the names of the winners, noting the exceptionally high quality of the submissions, which had rendered the committee's choice pleasantly difficult. On Friday, Edelman presented his results on eigenvalues and condition numbers of random matrices. It was generally agreed that his results were beautiful and that his presentation was delivered with clarity and style.

Sad to say, Ong had some sort of visa problem with the U.S. Immigration Service and was not able to make the trip to Sweden to present her results. It was rumored that INS thought her Green's function should also have a green card (what else?), but in all fairness, this report is totally unsubstantiated.

The audience was invited to confirm an odd anomaly—the Cray computations of both (62.0 x 63.0)/62.0 and (63.0 x 63.0)/63.0 return values that are not integers.

Informal Talks

Evening sessions, spontaneously organized to supplement the formally scheduled daytime talks, were very well attended. One of the informal talks, given by Velvel Kahan immediately after the Thursday banquet, actually served as the postbanquet entertainment. His lively and provocative discourse provided more detail about Cray arithmetic. The audience was invited to confirm an odd anomaly—the Cray computations of both (62.0 x 63.0)/62.0 and (63.0 x 63.0)/63.0 return values that are not integers.

Hans Schneider made some remarks in support of ILAS, the International Linear Algebra Society. Speaking to professionals whose very business it is to understand the notions of "less than" and "greater than," Schneider noted that the annual dues for this organization amounted to less than the cost of two Swedish beers.

For anyone interested (and there were many), Cleve Moler demonstrated a preliminary version of a proposed addition to Matlab for the handling and graphing of sparse matrices.

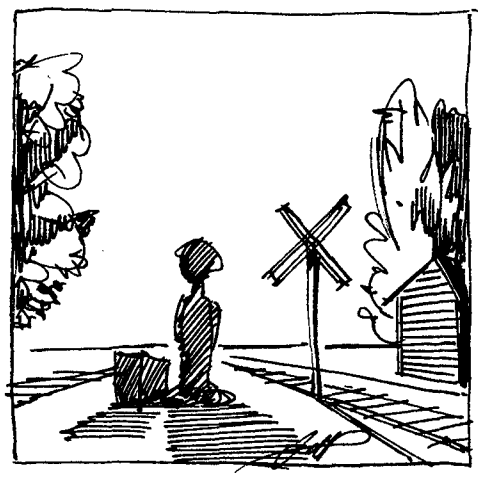
Local Color

Wednesday afternoon was set aside for an excursion to a wildlife refuge on an island off the coast. Many cheerfully piled into the Skandia buses for the trip to the harbor, where a roofless ferry awaited us. Only after we reached the island did the rains begin. Just a drizzle, nothing that could result in any diminution of The Experience. However, those of us who failed to bring umbrellas or raincoats were left in a state of soggy contrition after our return trip on the roofless ferry. At least the bus was covered.

The last day of the conference was June 22, the longest day of the year. Midsummer's Day, as it is known in Sweden, is marked with folk-dancing around special poles. But given the ghost-town emptiness of the streets, it is apparently mainly a time to stay at home and celebrate. For me, a Midsummer's Day departure from Halmstad meant a train station that had no passengers, no station master, and, it appeared for a while, no train. But the train finally did appear, like a soundless Flying Dutchman with only one or two passengers (strangers, like me, to the Swedish ways).

Householder XI was a remarkably good meeting—the organizers are to be congratulated, and special thanks are due to Åke Bjorck for all his attention and consideration!

Several participants went on to other conferences on leaving Halmstad. Golub, along with Nancy Nichols, Paul van Dooren, and several others, stayed in Sweden to attend the meeting of SIAM's Nordic Section in Stockholm immediately following Householder XI. Demmel, Plemmons, and Young were off to Moscow, where they were to lecture at the USSR Academy of Sciences.



John de Pillis, a professor of mathematics and computer science at the University of California at Riverside, wrote and illustrated this article. He thanks Randy Bramley and Bob Plemmons for the use of their notes and Gene Golub for his observations.

Gene Golub and Tony Chan are the organizers of the next Householder Conference, Householder XII, which will be held at the University of California's Lake Arrowhead Conference Center in southern California in June 1993. Watch the SIAM News *Calendar for further details.*

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