What to do with a million lines of Fortran code? Managers at every major Fortran installation are asking this question every day. Newer programming languages (C and ADA), and newer computer architectures (parallel, data flow) pose a serious dilemma. How will the algorithms and mathematical techniques in tens of thousands of Fortran programs be moved to these environments? Further, since no language will dominate the science and engineering arena, another question arises. With strained programming staffs and budgets, how will algorithms be maintained in multiple languages and architectures?

There are three solutions. The first is to hire additional staff to translate programs across languages, to coordinate and maintain large libraries of subroutines in the different languages using existing software tools. Most of the conversion will be from Fortran to C and ADA, a project with many unresolved issues (in particular array handling). The solution is unfeasible economically, when you consider the number of combinations of environments (a language out of Fortran, C, ADA, any other) with a new architecture (out of Cray, FPS, CSPI, Alliant, etc.). The staff requirements and overhead will be excessive, even if you could find enough people willing to do the very boring work of translating and maintaining software.

The second solution is to develop completely automatic language translation programs, using all of the breakthroughs in software engineering, language theory, and artificial intelligence. The problems here are many. First no one has developed an efficient automatic translation system. The few on the market either are not completely automatic, or produce very ugly and inefficient code. It is impossible for a computer (and even many humans) to translate a piece of Fortran code that operates on different dimensioned arrays passed to the same subroutine with some EQUIVALENCE and COMMON usage. Further you don't want exact translations. Fortran programs were written within the limitations of Fortran, when in the newer languages the algorithms can be expressed more clearly and efficiently.
The third, and most practical solution, which STO and a few others have adopted, uses an intermediate language that is easy to translate Fortran into, and allows for source code in others languages to be generated automatically. The intermediate language is the union of all other programming languages (and the trick is to create a useful union) with some extensions that reflect the nature of the algorithms. The benefits of this approach are many. First the original Fortran program has to be rewritten only once, and then only parts of the program; most Fortran code passes through without any change (i.e. assignment and simple IF statements). Software tools are provided to ease this initial translation. Once in the intermediate language, the algorithm can then be obtained in any other language automatically.

Some of the conversions (as options) include array indice reversal (where A(R(C,D),B(F,G)) in Fortran becomes in C A[E(G)[F]][B(D)[C]]), many precision support (constants appended with E0,DO etc., subroutine and function names are suffixed, ABSR, ABSD, ABSG), and insertion of timing/frequency analysis. Manual conversion introduces errors, hindering the testing of the translated programs.

Figure 1 shows an example of a subroutine from the Eispack library in ten different languages. First, the subroutine is rewritten in STO's intermediate language, and is shorter than most of the final programs. Then, the subroutine is automatically generated in the other languages (and back into Fortran). We have successfully converted Linpack (and its test drivers), and produced tested C, Pascal, Basic, and Fortran 77 versions (and if anyone has compilers for other languages, we will provide the code for verification).

What are the disadvantages of this approach? There are two main problems, which are present even if you adopt another solution to converting Fortran programs. The first problem is that many of the newer languages are incapable of supporting numerical algorithms as easily as Fortran does. Pascal does not allow subroutines to accept arrays of different sizes, making subroutine libraries all but impossible (actually some Pascal compilers do, but there are at least two incompatible implementations). Modula-2, a (weak) attempt to fix Pascal, also doesn't allow subroutines to handle different sized multiple dimensional arrays (only 1D). Neither Pascal nor Modula-2 allow complex numbers (the suggested solution of using records and turning arithmetic expressions into series of subroutine or function calls being pathetic). These languages also provide limited multiple precision support, and not the most useful looping control structures. Modula has no GOTO, and while most GOTOS can be removed from Fortran subroutines, some very important subroutines have GOTOS that are extremely difficult to remove. At least in C and ADA you can use GOTOS for these tricky subroutines (like the *INVIT algorithms in the Eispack library). C supports Fortran programs well; its only deficiency is the lack of COMPLEX numbers used with +* (hint ANSI committee!!)

D.1.3.2
The other main problem arises with ADA. ADA has many powerful capabilities that forces you to start from scratch to fully take advantage of ADA. Generics, exceptions, and other features can only be generated if the intermediate language is as expressive as ADA, in which case just use ADA/DIANA to begin with. Unfortunately there are many installations with millions of lines of Fortran code that probably don't need all of the power of ADA, in which case automated translation becomes reasonable. Then languages like Occam (for parallel processing) require additional design considerations (in this case to efficiently use the parallel architecture).

At STO, we are undertaking a project to convert SLATEC to multiple languages via the intermediate language; when successful, packages such as Spice, Nastran, and Gaussian 84 will be converted. These projects are quite important to the design of the intermediate language in the translation challenges provided. It is important to realize that the recoding is a small part of the translation process. Creating software environments for multi-language software maintenance is the more critical task. To do so will require flexible software generation programs, in particular, those based on the use of an intermediate language.

The approach taken by STO and others (Boyle at Argonne, Waters at MIT, de Maine at Auburn, Diana for ADA, Lexeme) of using an intermediate language and associated software tools will allow Fortran installations to move their Fortran programs into new environments with minimal problems. While not a perfect solution, it is less costly than having larger programming staffs, and more realistic than relying on completely automatic translators.
TYPE ARRAY1DR IS ARRAY (INTEGER RANGE <> ) OF REAL;
TYPE ARRAY2DR IS ARRAY (INTEGER RANGE <> ,
                        INTEGER RANGE <> ) OF REAL;

PROCEDURE ORTRNR (N: IN INTEGER; LOW: IN INTEGER;
   HIGH: IN INTEGER; A: IN ARRAY2DR;
   ORT: IN OUT ARRAY1DR; Z: IN OUT ARRAY2DR) IS
   I, J, KL, MM, MP, MP1: INTEGER;
   G: REAL;
BEGIN
    --
    --
    --
    --
    --
    EISPACK SUBROUTINE ORTRAN IN ADA
    --
    --
    FOR J IN 1..N LOOP
      FOR I IN 1..N LOOP
        Z(I,J) := 0.0E+0 ;
      END LOOP;
      Z(J,J) := 1.0E+0 ;
    END LOOP;
    KL := HIGH - LOW - 1 ;
    FOR MM IN 1..KL LOOP
      MP := HIGH - MM ;
      IF A(MP,MP - 1) \= 0.0E+0 THEN
        MP1 := MP + 1 ;
        FOR I IN MP..HIGH LOOP
          ORT(I) := A(I,MP - 1) ;
        END LOOP;
        FOR J IN MP..HIGH LOOP
          G := 0.0E+0 ;
          FOR I IN MP..HIGH LOOP
            G := G + ORT(I) * Z(I,J) ;
          END LOOP;
          G := (G / ORT(MP)) / A(MP,MP - 1) ;
          FOR I IN MP..HIGH LOOP
            Z(I,J) := Z(I,J) + G * ORT(I) ;
          END LOOP;
        END IF;
      END LOOP;
    END ;
D.1.3.4
EISPACK SUBROUTINE ORTRAN IN C

```c
ORTRAN (N, LOW, HIGH, A, ORT, Z)
int N, LOW, HIGH;
double **A, **Z, *ORT;
{
    int I, J, KL, MM, MP, MP1;
double G;
/***/
/*
   for ( J = 1; J <= N; J += 1 ) {
      for ( I = 1; I <= N; I += 1 ) {
           Z[I][J] = 0.0E+0;
      }
      Z[J][J] = 1.0E+0;
   }
   KL = HIGH - LOW - 1;
   for ( MM = 1; MM <= KL; MM += 1 ) {
      MP = HIGH - MM;
      if (A[MP][MP-1] != 0.0E+0) {
          MP1 = MP + 1;
          for ( I = MP1; I <= HIGH; I += 1 ) {
             ORT[I] = A[I][MP-1];
          }
      }
      for ( J = MP; J <= HIGH; J += 1 ) {
          G = 0.0E+0;
          for ( I = MP; I <= HIGH; I += 1 ){
             G = G + ORT[I] * Z[I][J];
          }
          G = (G / ORT[MP]) / A[MP][MP-1];
          for ( I = MP; I <= HIGH; I += 1 ){
             Z[I][J] = Z[I][J] + G * ORT[I];
          }
      }
   }
}
*/
```
SUBROUTINE ORTRND (N, LOW, HIGH, A, LDA, ORT, Z, LDZ)
INTEGER LDA, LDZ
INTEGER N, LOW, HIGH
DOUBLE PRECISION A(LDA,1)
DOUBLE PRECISION Z(LDZ,1), ORT(1)
INTEGER I, J, KL, MM, MP, MP1
DOUBLE PRECISION G

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EISPACK SUBROUTINE ORTRAN IN FORTRAN

DO 210 J = 1, N
   DO 190 I = 1, N
      Z(J,I) = 0.0D0
   CONTINUE
   Z(J,J) = 1.0D0

210 CONTINUE
KL = HIGH - LOW - 1
IF (KL .LT. 1) GOTO 411
DO 410 MM = 1, KL
   MP = HIGH - MM
   IF (A(MP - 1,MP) .EQ. 0.0D0) GOTO 400
   MP1 = MP + 1
   DO 290 I = MP1, HIGH
      ORT(I) = A(MP - 1, I)
   CONTINUE
   DO 390 J = MP, HIGH
      G = 0.0D0
      DO 340 I = MP, HIGH
         G = G + ORT(I) * Z(J,I)
      CONTINUE
      G = (G / ORT(MP)) / A(MP - 1, MP)
      DO 380 I = MP, HIGH
         Z(J,I) = Z(J,I) + G * ORT(I)
      CONTINUE
380 CONTINUE
390 CONTINUE
410 CONTINUE
411 CONTINUE
RETURN
END
PROCEDURE: ORTRNQ ()

INTEGER ARG: N
INTEGER ARG: LOW
INTEGER ARG: HIGH
ANY ARG: A
ANY ARG: ORT/VAR
ANY ARG: Z/VAR

END PROCEDURE

PUBLIC: ORTRNQ

PROCEDURE: ORTRNQ

INTEGER I, J, KL, MM, MF, MP1
REAL G

EISPACK SUBROUTINE ORTRAN IN BASIC

REM

FOR J = 1 TO N
FOR I = 1 TO N
  Z(I,J) = 0.0E+0
  Z(J,J) = 1.0E+0
NEXT

IF KL < 1 THEN GOTO 821
FOR MM = 1 TO KL
  MP = HIGH - MM
  IF A(MP,MP - 1) = 0.0E+0 THEN 800
  MP1 = MP + 1
  FOR I = MP1 TO HIGH
    ORT(I) = A(I,MP - 1)
    NEXT
    FOR J = MP TO HIGH
      G = 0.0E+0
      FOR I = MP TO HIGH
        G = G + ORT(I) * Z(I,J)
        NEXT
        G = (G/ORT(MP)) / A(MP,MP - 1)
        FOR I = MP TO HIGH
          Z(I,J) = Z(I,J) + G * ORT(I)
          NEXT
        NEXT
      NEXT

REM END OF IF BLOCK
NEXT

REM END OF IF BLOCK
RETURN
END PROCEDURE

D.1.3.7
ORTRNR:
PROC (N, LOW, HIGH, A, ORT, Z);
DCL (N, LOW, HIGH) FIXED BIN (15);
DCL A(*,*) FLOAT DEC (6);
DCL (Z(*,*), ORT(*)) FLOAT DEC (6);
DCL (I, J, KL, MM, MP, MP1) FIXED BIN (15);
DCL G FLOAT DEC (6);
/
EISPACK SUBROUTINE ORTRAN IN PLI
/*
DU J = 1 TO N;
   DO I = 1 TO N;
      Z(I,J) = 0.0E+0;
   END;
   Z(J,J) = 1.0E+0;
END;
KL = HIGH - LOW - 1;
IF KL >= 1 THEN DO;
DO MM = 1 TO KL;
   MP = HIGH - MM;
   IF A(MP,MP - 1) /= 0.0E+0 THEN DO;
      MP1 = MP + 1;
      DO I = MP1 TO HIGH;
         ORT(I) = A(I,MP - 1);
      END;
   DO J = MP TO HIGH;
      G = 0.0E+0;
      DO I = MP TO HIGH;
         G = G + ORT(I) * Z(I,J);
      END;
      G = (G / ORT(MP)) / A(MP,MP - 1);
   DO I = MP TO HIGH;
      Z(I,J) = Z(I,J) + G * ORT(I);
   END;
END;
END;
END ORTRNR;
PROC ORTRNR (N, LOW, HIGH, A: ORT, Z); BEGIN
ITEM N S;
ITEM LOW S;
ITEM HIGH S;
TABLE A[*,*] F;
TABLE Z[*,*] F;
TABLE ORT[*] F;
ITEM I S;
ITEM J S;
ITEM KL S;
ITEM MM S;
ITEM MP S;
ITEM MP1 S;
ITEM G F;
""
""
""
""
EISPACK SUBROUTINE ORTRAN IN JOVIAL"
""
""
""
""
FOR J : 1 BY 1 WHILE J <= N ;BEGIN
  FOR I : 1 BY 1 WHILE I <= N ;BEGIN
    Z[I,J] = 0.0E+0;
    Z[J,J] = 1.0E+0;
  END;
KL = HIGH - LOW - 1;
IF KL >= 1; BEGIN
  FOR MM : 1 BY 1 WHILE MM <= KL ;BEGIN
    MP = HIGH - MM;
    IF A[MP,MP - 1] <> 0.0E+0; BEGIN
      MP1 = MP + 1;
      FOR I : MP1 BY 1 WHILE I <= HIGH ;BEGIN
        ORT[I] = A[I,MP - 1];
      END;
      FOR J : MP BY 1 WHILE J <= HIGH ;BEGIN
        G = 0.0E+0;
        FOR I : MP BY 1 WHILE I <= HIGH ;BEGIN
          G = G + ORT[I] * Z[I,J];
        END;
        G = (G / ORT[MP]) / A[MP,MP - 1];
        FOR I : MP BY 1 WHILE I <= HIGH ;BEGIN
          Z[I,J] = Z[I,J] + G * ORT[I];
        END;
      END;
    END;
  END;
END;
ORTRAN;
END
TYPE ARRAY1DR = SUPER ARRAY [1..*] OF REAL8;
TYPE ARRAY2DR = SUPER ARRAY [1..*,1..*] OF REAL8;

PROCEDURE ORTRNR (N:INTEGER; LOW:INTEGER;
               HIGH:INTEGER; VAR A:ARRAY2DR;
               VAR ORT:ARRAY1DR; VAR Z:ARRAY2DR);
VAR I, J, KL, MM, MP, MP1: INTEGER;
    G: REAL8;
BEGIN
    (*
    EISPACK SUBROUTINE ORTRAN IN PASCAL
    *)
    FOR J := 1 TO N DO BEGIN
        FOR I := 1 TO N DO BEGIN
            Z[I,J] := 0.0E+0;
            END;
        Z[J,J] := 1.0E+0;
    END;
    KL := HIGH - LOW - 1;
    IF (KL > 1) THEN BEGIN
        FOR MM := 1 TO KL DO BEGIN
            MP := HIGH - MM;
            IF (A[MP,MP - 1] <> 0.0E+0) THEN BEGIN
                MP1 := MP + 1;
                FOR I := MP1 TO HIGH DO BEGIN
                    ORT[I] := A[I,MP - 1];
                END;
                FOR J := MP TO HIGH DO BEGIN
                    G := 0.0E+0;
                    FOR I := MP TO HIGH DO BEGIN
                        G := G + ORT[I] * Z[I,J];
                    END;
                    G := (G/ORT[MP]) / A[MP,MP - 1];
                    FOR I := MP TO HIGH DO BEGIN
                    END;
                END;
            END;
        END;
    END;
END; (ORTRNR)
CONST NEIG =
TYPE ARRAY1DR = ARRAY [1..NEIG] OF REAL;
TYPE ARRAY2DR = ARRAY [1..NEIG,1..NEIG] OF REAL;

PROCEDURE ORTRNR (N:INT; LOW:INT; HIGH:INT;
   A:ARRAY2DR; VAR ORT:ARRAY1DR;
   VAR Z:ARRAY2DR);
VAR I, J, KL, MM, MP, MP1: INT;
G: REAL;
(*
   EISPACK SUBROUTINE ORTRAN IN MODULA-2
*)
BEGIN
   FOR J := 1 TO N DO
      FOR I := 1 TO N DO
         Z[I,J] := 0.0E+0;
      END;
      Z[J,J] := 1.0E+0;
   END;
   KL := HIGH - LOW - 1;
   IF (KL >= 1) THEN
      FOR MM := 1 TO KL DO
         MP := HIGH - MM;
         IF (A[MP,MP - 1] <> 0.0E+0) THEN
            MP1 := MP + 1;
            FOR I := MP1 TO HIGH DO
               ORT[I] := A[I,MP - 1];
            END;
            FOR J := MP TO HIGH DO
               G := 0.0E+0;
               FOR I := MP TO HIGH DO
                  G := G + ORT[I] * Z[I,J];
               END;
               G := (G / ORT[MP]) / A[MP,MP - 1];
               FOR I := MP TO HIGH DO
               END;
            END;
         END;
      END;
   END;
END;
END
EISPACK SUBROUTINE ORTRAN IN TURING

FOR J : 1..N
  FOR I : 1..N
    Z(I,J) := 0.0e+0
  END FOR
  Z(J,J) := 1.0e+0
END FOR

KL := HIGH - LOW - 1
IF KL >= 1 THEN
  FOR MM : 1..KL
    MP := HIGH - MM
    IF A(MP,MP - 1) = 0.0e+0 THEN
      MP1 := MP + 1
    FOR I : MP1..HIGH
      ORT(I) := A(I,MP - 1)
    END FOR
    FOR J : MP..HIGH
      G := 0.0e+0
      FOR I : MP..HIGH
        G := G + ORT(I) * Z(I,J)
      END FOR
      G := (G/ORT(MP)) / A(MP,MP - 1)
    FOR I : MP..HIGH
      Z(I,J) := Z(I,J) + G * ORT(I)
    END FOR
  END IF
END FOR
ENDIF
ENDIF
END ORTRNR
EISPACK SUBROUTINE ORTRAN IN ALGOL-68

PROC ORTRNR = ( INT N, INT LOW, INT HIGH, REAL A, REAL ORT, REAL Z ) VOID:

BEGIN

CO

INT I, J, KL, MM, MP, MP1;
REAL G;
FOR J FROM 1 TO N DO
FOR I FROM 1 TO N DO
Z[I,J] := 0.0e+0;
OD;
Z[J,J] := 1.0e+0;
OD;
KL := HIGH - LOW - 1;
IF KL GE 1 THEN
FOR MM FROM 1 TO KL DO
MP := HIGH - MM;
IF A[MP,MP - 1] NE 0.0e+0 THEN
MP1 := MP + 1;
FOR I FROM MP1 TO HIGH DO
ORT[I] := A[I,MP - 1];
OD;
FOR J FROM MP TO HIGH DO
G := 0.0e+0;
FOR I FROM MP TO HIGH DO
G := G + ORT[I] * Z[I,J];
OD;
G := (G/OR[MP]) / A[MP,MP - 1];
FOR I FROM MP TO HIGH DO
OD;
FI;
OD;
FI;
RETURN;
END

D.1.3.13