BSTALN - A COMPUTER IMPLEMENTATION OF AN ALGORITHM FOR THE BEST MECHANICAL ALIGNMENT PROBLEM

J.W. Bandler, M.A. El-Kady, W. Kellermann
and W.M. Zuberek

SOS-83-13-U

September 1983

BSTALN - A COMPUTER IMPLEMENTATION OF AN ALGORITHM FOR THE BEST MECHANICAL ALIGNMENT PROBLEM

J.W. Bandler, M.A. El-Kady, W. Kellermann and W.M. Zuberek

Abstract

This report presents a computer implementation of a recently developed minimax approach to the best mechanical alignment problem in two dimensions. The Fortran program BSTALN for solving the problem is described. The program employs the MMLC package for linearly constrained minimax optimization. The data and the test results on a practical problem of part alignment in manufactured mechanical systems illustrate the use of the program. The program and documentation have been developed for the CDC 170/730 system with the NOS 1.4 level 552 operating system and the Fortran Extended (FTN) version 4.8 compiler. This document is a user's manual for the program.

This work was supported by the Natural Sciences and Engineering Research Council of Canada under Grants A7239, G0647 and A1708.

The authors are with the Simulation Optimization Systems Research Laboratory and the Department of Electrical and Computer Engineering, McMaster University, Hamilton, Canada L8S 4L7.

M.A. El-Kady is also with Ontario Hydro, Toronto, Canada.

W.M. Zuberek is on leave from the Institute of Computer Science, Technical University of Warsaw, Warsaw, Poland. He is now with the Department of Electrical Engineering, Texas A&M University, College Station, TX 77843, U.S.A.

I. INTRODUCTION

This report presents a computer implementation of a recently developed minimax approach to the best two-dimensional mechanical alignment problem [1]. The Fortran program BSTALN for solving the problem employs the MMLC package for linearly constrained minimax optimization [2]; the package MMLC must thus be also available when BSTALN is used. The program has been tested for seven sets of data [3] supplied by the Woodward Governor Company. The data resulted from practical problems of part alignment in manufactured mechanical systems and have been collected from inspecting actual parts. The results of running the program for a test problem are also included.

The BSTALN program is a set of Fortran IV subroutines for the CDC 170/730 system. At McMaster University it is available in the group indirect file BSTALN under the charge RJWBAND. The data files DATA1, DATA2, ..., DATA7 are available as group indirect files under the charge RJWBAND.

The local data file required by the program has a different name, SAMPLE. In this case, to run the program the following NOS commands can be used to fetch (and rename) the data file and to run the program:

/GET, SAMPLE = DATA1/GR.	(or DATA2, ..., DATA7) - fetch the data,
/GET, BSTALN, LIBRMML/GR.	- fetch the program and the library,
/LIBRARY, LIBRMML.	- indicate the library to the loader,
/FTN, ..., GO.	- compile, load and execute the program.

A Fortran listing of the BSTALN program is contained in [4].

II. STRUCTURE OF THE PROGRAM

The structure of the program is shown in Fig. 1. The main segment is BSTALN. It reads the data from the input file SAMPLE, prints the data, calls subroutine FDF at the starting point, calls subroutine PRSRCH and prints the

final results. The subroutine PRSRCH organizes the workspace memory for SEARCH and calls SEARCH. The subroutine SEARCH implements the decision-tree structure described in [1]. It calls SOLVER and INSRCH. The subroutine SOLVER prepares parameters and calls the minimax optimization routine MMLA1Q. The subroutine INSRCH eliminates identical entries in the decision-tree structure. The subroutine FDF performs the transformation of coordinates, evaluates error functions and final derivatives. It calls TOLCIR, TOLXY, TOLXR and TOLYR. The subroutines TOLCIR, TOLXY, TOLXR and TOLYR calculate the error function and its derivatives for the circular, rectangular, X-R and Y-R tolerance regions, respectively.

III. STRUCTURE OF THE INPUT DATA

The data for the best alignment program is organized in the form of separate data files. Each data file contains information concerning only one sample. The first record of the file contains the total number of points of the sample, parameter for selecting candidates for deletion, the text "SAMPLE NO:", the number of the sample and in brackets text "NAME:", and the name of the sample. The second and the next records have the following structure:

[tol.code] [origin code] [actual dim.x] [actual dim.y] [parameter T1]

[parameter T2] [parameter T3] [parameter T4].

The first two numbers are integers and the remaining six are real. The tolerance code is one of four (0, 12, 13, 23), where

0 - the code for the circular tolerance region,

12 - the code for the rectangular tolerance region,

13 - the code for the X-R tolerance region,

23 - the code for the Y-R tolerance region.

Any point with an origin code of 0 is referenced to the origin of x=0.0, y=0.0. Any other origin code refers to the point by that number on the same sample. For instance, for an origin code of 4, the actual x and y dimensions are measured from the actual x and y dimensions of point number 4.

Each tolerance region is described by four parameters T1, T2, T3, T4, which depend on the type of tolerance region and have the following interpretation. For the circular tolerance region T1, T2, T3 are the x and y coordinates of the center and the radius of the tolerance region, respectively. For the rectangular tolerance region T1, T2, T3 and T4 are the x_L, x_U, y_L and y_U dimensions of the tolerance region, respectively. For the X-R tolerance region T1, T2, T3 and T4 are the x_L, x_U, R_L and R_U dimensions of the tolerance region, respectively. For the Y-R tolerance region T1, T2, T3 and T4 are the y_L, y_U, R_L and R_U dimensions of the tolerance region, respectively.

Example 1

The following data file is an example of a data file for the BSTALN program.

```
5 0.990  SAMPLE NO.: 1 (NAME:#692)
 0  00.0000  0.0000  0.0000  0.0000  0.0010  0.0000
12  0-0.8800 1.3682  -0.8780 -0.8750 1.3690  1.3720
12  00.6589  0.7499  0.6610  0.6630  0.7500  0.7520
12  00.8990  -0.4414 0.8990  0.9010  -0.4410 -0.4380
12  0-0.5635 -1.5254 -0.5650 -0.5620 -1.5250 -1.5220
```

IV. TEST RESULTS ON A PRACTICAL PROBLEM

The program BSTALN has been run for seven sets of data [3] supplied by the Woodward Governor Company. The output from the program contains input data for the best alignment problem, error functions at the starting point, results of minimax optimization at each stage of the algorithm together with the number of iterations and the number of shifts of the minimax algorithm, a summary of results at each stage and the final results, which include variables and functions at the solution, number of deleted points and coordinates of translated reference points (if any).

Example 2

The following computer output illustrates the results of running the BSTALN program for a test problem for which the data file is given in Example 1.

INPUT DATA FOR THE BEST ALIGNMENT PROBLEM DATE : 83/06/29 TIME : 12.05.56.

TOTAL NUMBER OF HOLES OF THE SAMPLE: 5 HOLES C SAMPLE NO.: 1 (NAME:#692)

I	KTC(I)	KOC(I)	XA(I)	YA(I)	T1(I)	T2(I)	T3(I)	T4(I)
1	0	0	0.000000	0.000000	0.000000	0.000000	.001000	0.000000
2	12	0	-.880000	1.368200	-.878000	-.875000	1.369000	1.372000
3	12	0	.658900	.749900	.661000	.663000	.750000	.752000
4	12	0	.899000	-.441400	.899000	.901000	-.441000	-.438000
5	12	0	-.563500	-1.525400	-.565000	-.562000	-1.525000	-1.522000

ERROR FUNCTIONS AT THE STARTING POINT

1	-1.0000000E-03
2	2.0000000E-03
3	2.1000000E-03
4	4.0000000E-04
5	4.0000000E-04

RESULT OF MINIMAX OPTIMIZATION (RETURN: 1) 3.6078337E-04 N.IT: 12 N.SH: 1

STAGE: 0 FMAX: 3.6078337E-04

1	1	3.6078337E-04
2	2	-3.1240099E-04
3	3	3.6078337E-04
4	4	3.6078337E-04
5	5	-9.9390625E-04

RESULT OF MINIMAX OPTIMIZATION (RETURN: 3) -6.4566765E-04 N.IT: 25 N.SH: 2

1	1.8703916E-03	5	-6.4568441E-04
2	2.0952197E-03	2	-6.7804852E-04
3	-1.1678011E-03	3	-6.4567620E-04
		4	-6.4566765E-04

```
RESULT OF MINIMAX OPTIMIZATION (RETURN: 1)  1.8124698E-04     N.IT: 10   N.SH:  1

RESULT OF MINIMAX OPTIMIZATION (RETURN: 3)  3.1002078E-04     N.IT: 26   N.SH:  2


SOLUTION (TYPE: 0)

                              1.8703916E-03
                              2.0952197E-03
                             -1.1678011E-03

MAX ERROR AT THE SOLUTION:    -6.4566765E-04

                          5  -6.4568441E-04
                          2  -6.7804852E-04
                          3  -6.4567620E-04
                          4  -6.4566765E-04

NUMBER OF DELETIONS:                      1

                          1   1.0000000E+99

TOTAL EXECUTION TIME :    .603 SECONDS
```

V. REFERENCES

[1] J.W. Bandler, M.A. El-Kady, W. Kellermann and W.M. Zuberek, "A minimax approach to the best mechanical alignment problem", Department of Electrical and Computer Engineering, McMaster University, Hamilton, Canada, Report SOS-82-10-R, 1982. Also to appear in ASME J. of Mechanisms, Transmissions, and Automation in Design.

[2] J.W. Bandler and W.M. Zuberek, "MMLC - a Fortran package for linearly constrained minimax optimization", Department of Electrical and Computer Engineering, McMaster University, Hamilton, Canada, Report SOS-82-5-U/L, 1982.

[3] Woodward Governor Company, Rockford, IL, 61101, Sample data sent to McMaster University, February 23, 1982.

[4] J.W. Bandler, M.A. El-Kady, W. Kellermann and W.M. Zuberek, "BSTALN - a computer implementation of an algorithm for the best mechanical alignment problem", Department of Electrical and Computer Engineering, McMaster University, Hamilton, Canada, Report SOS-83-13-L, 1983.

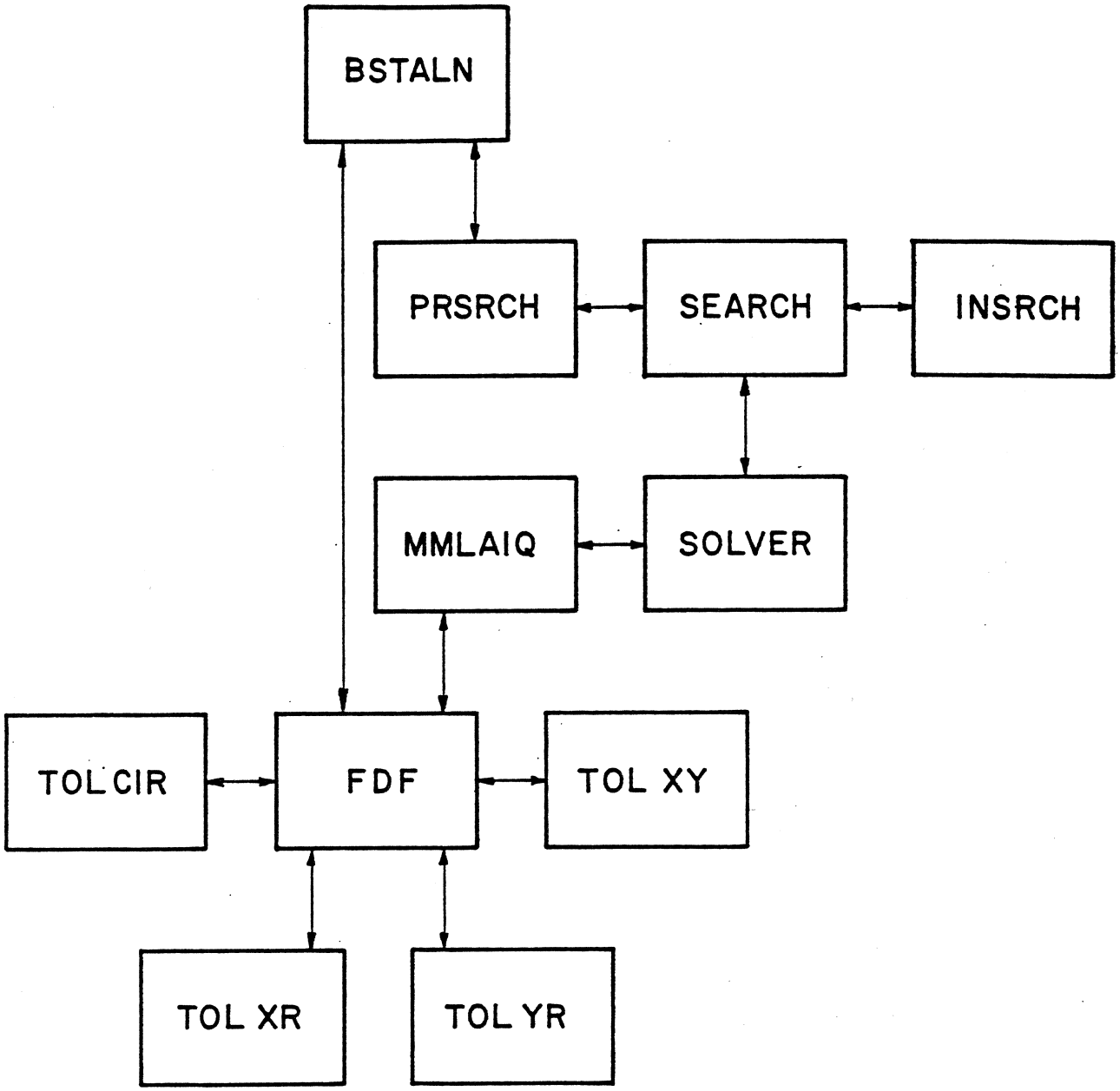

Fig. 1 Structure of the program for the best alignment problem.