An Investigation of Parallel Application I/O

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Abstract

This project has tested and evaluated the performance of model parallel applications using the Parallel Utility Libraries(PUL), Parallel File(PF). The software was developed specifically to provide scalable, parallel I/O facilities. Test applications characterising typical parallel applications have been written in the form of three C programs, Numerical, Filter and Database. Each application provides thorough testing of the effect of specific PUL-PF configuration attributes on parallel I/O performance. Such attributes include different parallel file distributions, local versus remote file server access, client/server ratio etc.

This report is intended to provide users who have applications that have particular parallel I/O intensive requirements with information on how to utilise PF to its fullest.

[Keywords: scalable performance parallel I/O, multiple file servers, client/server architecture, parallel file distribution, the atom, factorial experiments]

1 INTRODUCTION

Despite a constant increase in specialist parallel hardware, vendors software designed for these machines continues to lag behind. To contend with this problem, EPCC's Parallel Utility Library team(PUL), have developed Parallel File(PF) which provides scalable performance in one of the most active research areas of parallel computing, I/O.

One of the major problems in parallel computing is the input and output of data to and from a parallel program. Major bottlenecks occur when large amounts of data attempt to transfer through a single I/O stream, see Figure 1.

Whilst numerous advances in parallel I/O have led to the improvement of I/O performance, the majority have failed to provide a truly scalable solution. We define scalable performance I/O as maintaining a balance between computation and I/O bandwidth as the problem increases

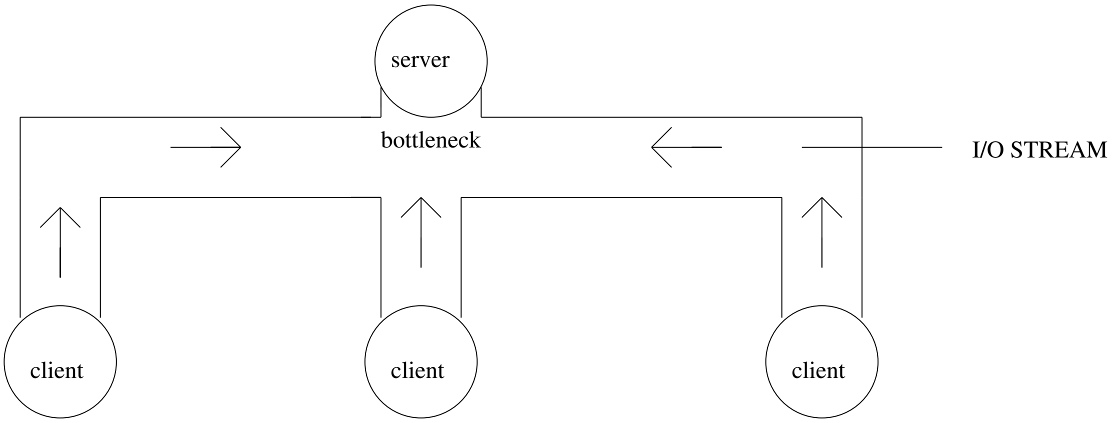

Figure 1: Bottlenecks in parallel I/O

There are techniques for increasing the transfer of data through a single I/O stream. Redundant Array Of Inexpensive Disks(RAID) uses an array of I/O disks, with blocks of data sub-divided into smaller blocks and stored on separate disks, each disk being an element in an array. Although this method extensively increases the I/O bandwidth, there is still an I/O bottleneck due to the single server controller which looks after the multiple disks. Parallel systems represent a solution to such I/O bottlenecks by increasing the number of I/O streams through which data is transferred.

The PUL team at EPCC are dedicated to developing common approach, parallel data management software. One recent addition to the library is PF, an extension to the non-scalable parallel I/O software, Global File Access(GF). This non-scalable limitation was due to having only a single server to deal with multiple client I/O requests. GF provided a high level of functionality, that has been incorporated by PF but to achieve truly scalable performance I/O, PF has introduced multiple servers.

2 SCOPE AND OBJECTIVES

In the course of this report we shall attempt to present the methodology behind testing the PUL-PF software and also compare PUL-PF's beneficial attributes with other parallel I/O systems.

PUL-PF was initially developed for the Geographical Information Systems Project(GIS). Brief background information on this project and how it led to the development of PF is presented in Section 3.

A detailed discussion of the features provided by PF and the client/server architecture around which PF is modelled, is presented in Section 4.

As stated, the main objective of this project was to test PF with typical parallel, I/O intensive, applications. Section 5 outlines the main characteristics of these applications along with a description of the three C programs, `numerical.c, filter.c and database.c`, developed to model typical parallel applications. Also provided in this section is a description of the input and output requirements for each application along with detail of the hardware and software used in developing and testing the programs.

Section 6 provides detailed information on the statistical methodology applied in this project.

Section 7 outlines the results obtained from multiple runs of the test applications followed by a discussion of the main conclusions drawn from analysis of these results.

Appendices A and B contain listings of the outfile analysis created by the statistical package, `Minitab`. Appendix C contains a basic user guide for anyone wishing to perform further experimentation.

3 G I S PROJECT

The Geographical Information Systems Project was carried out by staff at EPCC and the department of Geography along with support from a number of industrial companies. The overall aim of the project was to design prototype software demonstrating the effect of mapping a GIS onto parallel architectures.

GIS systems deal with large amounts of cartographic data which can be sub-divided into two main types.

1. Spatial data
2. Attribute data

Spatial data is characterised by locational data such as lines, points, areas and surfaces.

Attribute data describes the characteristics of a particular feature. For instance, typical projects which use GIS systems are traffic flow simulations. The attribute data stored in these databases would contain of information on vehicles, such as model, average speed, current destination etc.

This project had also anticipated considerable contributions to the development of EPCC's PUL, including the already established GF due to the fact that the GIS project was dealing with large data sets with I/O through one process, leading to the now familiar I/O bottleneck.

Unfortunately, due to lack of funding, the project was cancelled and this left PF without any real performance analysis of target applications.

4 PARALLEL FILE P F

PF provides structured and unstructured access to files shared amongst a group of processes, using EPCC'S message passing system, [Bruce R.A.A., 1993]. It is envisaged that in the foreseeable future PUL-PF will be ported to the standard, portable MPI [Bruce R.A.A.,]. To provide scalable performance I/O, PF has introduced the concept of multiple file servers.

4.1 Client/Server Architecture

The PF system is built around the concept of Client and Server roles. This concept is a useful one in software engineering and provides a flexible and attractive model for implementation of software in a distributed environment.

Briefly, the model supports behaviours of communication between systems components which are described as client or server behaviours. The purpose of the server role is to provide one or more services. A service may be either to provide some data or to act as a recipient of data (a repository). The client role models the behaviour of a component whereby a service is required from a server. The behaviour includes reading and writing data sets.

Figure 2, models an I/O intensive application.

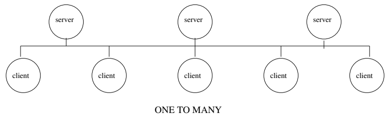

Figure 2: I/O intensive application

As mentioned earlier, it is desirable that the I/O bandwidth is balanced with the computational bandwidth. In I/O intensive algorithms there are no realistic procedures for re-balancing the architecture as the total I/O time increases at a faster rate than the computational time. Therefore, Ghosh, Goveas and Draper, [Ghosh J., 1993], suggest a suitable scalable architecture to consist of $n/log(n)$ servers and $log(n)$ clients. Obviously this is intended as a general purpose guideline, as some applications will have their own specific client/server scenarios.

4.2 Multiple Servers

GF's functionality has been incorporated into PF, the key difference being that PF extends GF's single server functionality to deal with multiple servers.

The aim is to have one server for each disk which has a segment of the parallel file.

PF supports server-pool partitioning. An application may wish to have a sub-group of servers dealing with read requests and a sub-group dealing with write requests. This may provide improved I/O performance in certain applications.

4.3 The Atom

The *atom* is a user-defined record type and can be of variable length. The applications developed in this project, will not allow the atom to be split across multiple servers in a Parallel File Distribution, hence the name atom as opposed to record. PF abandons the UNIX I/O bytes steam model which GF was supporting thus providing some structure to our data, allowing the model to enforce the idea of mapping the access patterns of an application to the distribution patterns of the file.

There are situations where an atom will have to be split across parallel file segments producing smaller data blocks known as *particles*.

4.4 Parallel File Access Modes

Parallel File Access Modes are used to determine the manner in which clients will access the parallel file.

For a more detailed description of PFAM's readers should refer to the PF concepts manual [Clarke L., 1993].

- single

  clients synchronously access the same data.

- multi

  clients synchronously access contiguous data, where the data is presented as block of atoms.

- random

  clients can independently access arbitrary data using a shared file pointer, therefore if a client changes the position of a file pointer then this will effect any subsequent read or write operations performed by other clients.

- independent

  each client has it's own local file pointer and therefore will not effect operations conducted by other processes.

4.5 Parallel File Distribution

Obviously we require ways in which files will be distributed amongst the servers, consequently this complicates the way in which clients will access the file. Ideally the file should be presented as a single logical unit to the client accessing it so that the I/O operations are unaware of the distribution of the parallel file.

A diagram along with a description of each P F D is now presented.

Figure 3 portrays a Multiple Instance distribution, where the serial file is simply replicated over each of the available disks.

Figure 4 portrays a Partition distribution. In this distribution, the serial file is split into `D` contiguous sections, where `D` is the number of disks.

Figure 5 portrays a Interleave distribution. In this distribution, the serial file is distributed `k mod D`, where `k` is the atom number `0...n-1` and `D` is the number of disks.

Figure 6 portrays a combination the Partition and Interleave distributions, Partition/Interleave. In this distribution, the serial file is viewed as containing blocks of atoms. The atoms are distributed according to `(k div B)mod D` where B is the number of atoms in each block. This is distribution is more transparent when thought of as the under-lying distribution for both Partition and Interleave. The Partition distribution is simply a Partition/Interleave with block size equal to the number of atoms stored on each disk. The Interleave distribution is a Partition/Interleave with block size 1.

For more information on PFD's and their implications, the reader should refer to [Clarke L., 1993].

5 APPLICATION IMPLEMENTATION

5.1 Introduction

This project analyses three types of parallel applications, `numerical, filter and database`. Each application is implemented as a separate C program.

These three programs shall be briefly described in this section.

Also discussed in this Section are the input requirements and the output generated for both of these programs, as well as a list of the software and hardware used in this project.

5.2 Software and Hardware requirements

All of these test applications have been written in the C programming language. Each application I/O test suite has been evaluated on specialist, parallel hardware, namely the Meiko SPARC CS1"hydra". The diagrams within this report have been developed using `Xfig` whilst the statistical package `Minitab` (V9,2 Windows) was used to provide structure to and analysis of varying PF configuration experiments.

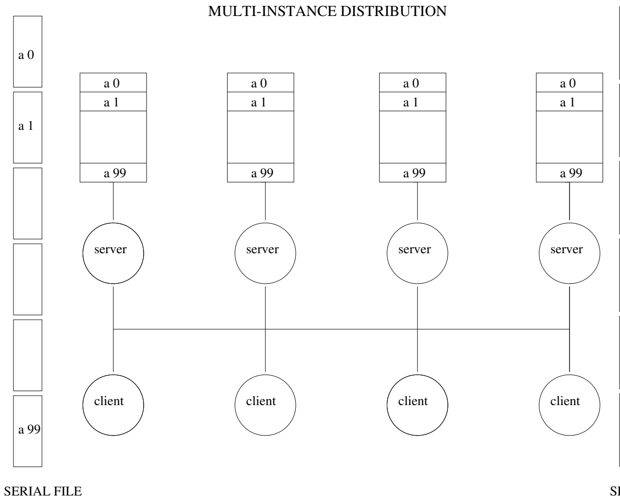

Figure 3: MULTI/INSTANCE

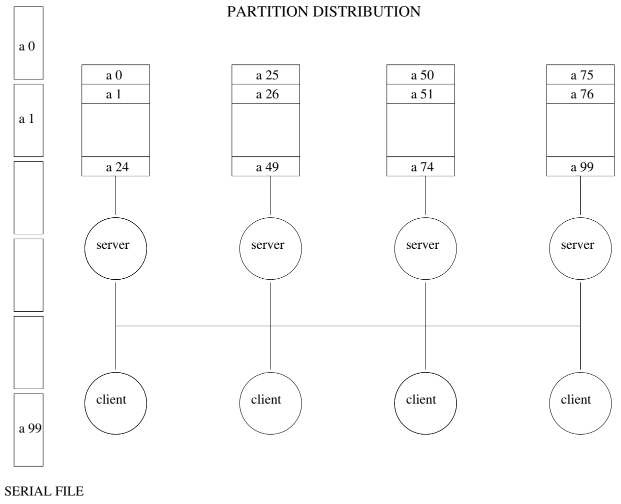

Figure 4: PARTITION

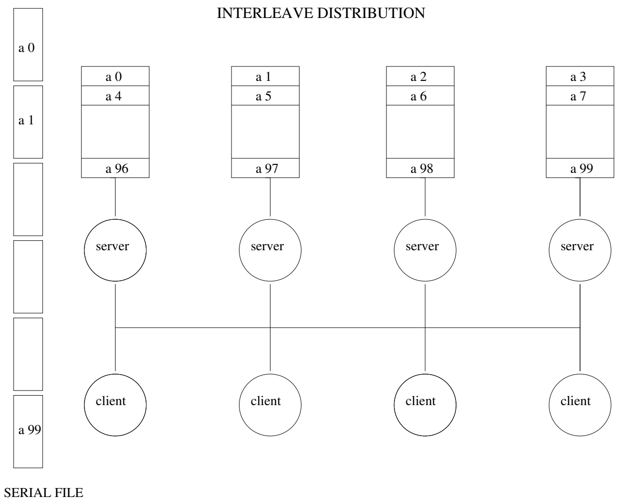

Figure 5: INTERLEAVE

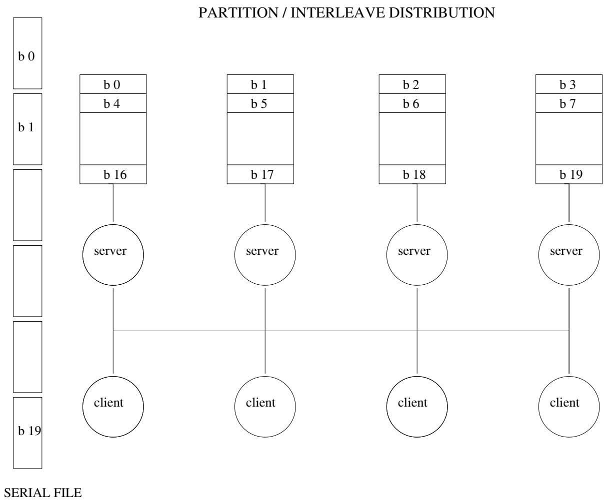

Figure 6: PARTITION/INTERLEAVE

Flag	Application	Function
-s	N,F,D	no. of servers
-c	N,F,D	no. of clients
-in	N,F,D	file for reading
-out	N,F	file for writing
-atom	N,F,D	maximum atom size (fixed or varied)
-fixvar	F,D	fixed or variable sized atoms
-file	N,F,D	serial file size
-where	N,F,D	local/remote disk
-pulpfd	N,F,D	type of parallel file distribution
-sub	N,F,D	no. of sub-groups for server pool partition
-arity	N,F,D	no. pf servers in each sub-group
-array	N,F,D	size of array 1D,2D and 3D
-block	N	atom block size for each client
-iter	N,F,D	no. of compute iterations
-read	N,F,D	no of servers associated with file
-access	N,F,D	local/remote server access

Table 1: Command line parser options

5.3 Instrumentation

The initial task in this project was to instrument PF allowing for efficient analysis of the PF configurations under observation. Instrumented PF library functions have been developed for each PF operation, which in addition to performing the associated function, time how long the operation takes to complete. Each time is recorded along with other statistics including, minimum/maximum time, average time, standard deviation and number of calls to operation.

Another requirement for PF instrumentation was to construct a command line parser which allows the user to specify how PF will configure during an application run. Table 1 lists each flag along with its associated function.

Finally, shell scripts have been written which perform multiple experimental runs for each application without the need for human supervision. This has allowed the experiments to be run over night, reducing variability from other uncontrollable factors such as other processor loads, see Section 6. Results files are produced for each processor for each experiment, along with a single results file containing cumulative average and standard deviation totals for each active processor. The totalled results file is produced using PUL-EM, which provides the facility to sum data distributed across a number of processors.

5.4 Application Introduction

Each application has been developed with a view to testing specific PF configurations. Anyone wishing to further experiment with any of the applications must ensure that specific parameters supplied, via the command line parser, are coherent with the assumptions defined in the User Guide H.

5.5 Numerical Application

Numerical applications involve the reading and writing of large data sets such as arrays. The majority of application work carried out at EPCC is numerical. Some of the properties which characterise the Numerical application developed in this project include:

- accepts linear,2D and 3D arrays
- fixed length atoms

  If desired can cope with variable sized atoms.
- separate input and output files

  Each client will read their own allocated block of atoms before commencing with the compute and writing phases.
- separate phases: input, compute and output

  One iteration in the compute stage corresponds to forwarding atom elements one position(i.e. element `n-1` becomes element `0` etc.).

The basic algorithm for the Numerical application involves ensuring that each client receives the correct serial atom for reading and writing. Figure represents how a number of clients read in a 2D array (in serial form):

5.6 Filter Application

The main characteristic of a Filter application is the overlap of compute and I/O phases. An example, practical application, involving a filter algorithm, would be an image processing pipeline. Some of the properties which characterise the Filter application developed in this project include:

- overlap of input,compute and output phases.

  Each client in the application will read in a single atom at a time, perform a compute iteration on that atom, then write out the atom to a separate file.
- variable length atoms(records)

5.7 Database Application

Database applications involve clients accessing data items randomly. Some of the properties which characterise the Database application developed in this project include:

- overlap of compute and I/O phases
- Independent PFAM
- single file for reading and writing

6 STATISTICAL ANALYSIS

6.1 Introduction

This section is intended to portray in detail information on the underlying statistics in this project. Therefore, the reader who is solely interested in the final conclusions may wish to skip this section and resort to the Minitab outfiles provided in the Appendices. Each outfile is provided with suitable

			X1			
		1	2	...	b	Row mean
X2	1	Y_{11}	Y_{12}	...	Y_{1b}	$\mu_{1.}$
	2	Y_{21}	Y_{22}	...	Y_{2b}	$\mu_{2.}$
	a	Y_{a1}	Y_{a2}	...	Y_{ab}	$\mu_{a.}$
	Col.Mean	$\mu_{.1}$	$\mu_{.2}$	...	$\mu_{.b}$	$\mu_{..}$

Table 2: Factorial Design

comments enabling the reader to be acquainted with enough information to be able to appreciate the final results and conclusions. The author felt it necessary to present in detail, the definitions of main effects and interactions as they are part of every statistical experiment performed. Other branches of statistics included in this project such as, ANOVA tables etc., will be dealt with in a more conservative manner with emphasis on outline rather than detail. The reader who may wish further information should refer to the statistics bible [G.E.P.Box, 1978].

6.2 Framework for analysing experiments with two or more factors

Two main questions have come to the fore-front of the analysis in this project;Which PF parameters have a significant effect in the way we configure parallel applications? What effect do these configurations have on the response variable? In response to these questions, tests on PF's I/O performance have been carried out involving the varying of numerous PF configuration attributes for each of the three test applications. What we are looking to obtain is trends in responses resulting from certain configurations applied to particular types of applications. For example, the time taken for a particular PF operation in the application FILTER may depend on the type of parallel file distribution, on the client/server ratio, on wether or not we are dealing with fixed/variable sized atoms, and so on. Analysing numerous factors at varying levels requires a great deal of thought in how to plan and design the levels of each factor for experimentation and also on how to analyse and validate the results. When analysing factors at various levels, simply varying one factor whilst varying all the other factors, is not an approach which will provide optimum analysis. To properly design the experiment we must change the factors together as the significance of certain factors are dependent on the setting of the levels of others.

6.3 Full factorial experiments

Factorial Experiments provide the framework for modelling experiments involving numerous factors at various levels. FE experiments not only allow us to analyse the main effects of factors but also possible significant, high/low order, interactions.

Full factorial experiments are generally carried out when there are no restrictions on economy in the number of experimental runs we can perform or when there are a small number of factors. It is usual in both full and fractional experiments to commence with a screening experiment where each factor has an associated 2 levels i.e. we have a 2^k number of experimental runs where k=number of factors(variables). For instance, if we have say 2 factors x1, x2 and both with an associated number of levels, a and b respectively(2^2=4 experimental runs), our factorial design, will have a layout similar to Table 2.

This type of design matrix is referred to as a saturated design as each column has an associated factor. From this design we can estimate a full four quantities: the overall mean, the two main effects and the second order interactions(between 1 and 2).

Let us define what we mean by main effects and interactions. Referring to our factorial design table, each of the four quantities is defined as follows:

- overall mean

$$\mu_{..} = \frac{1}{ab} \sum_{i=1}^{a} \sum_{j=1}^{b} \mu_{ij}$$

- the main effect of factor x1,α_i

$$\alpha_i = \mu_{i.} - \mu_{..}$$

where

$$\mu_{i.} = \frac{1}{b} \sum_{j=1}^{b} \mu_{ij} \qquad \text{and} \qquad \text{i = 1,2, \ldots,a}$$

- the main effect of factor x2,β_j

$$\beta_j = \mu_{.j} - \mu_{..}$$

where

$$\mu_{.j} = \frac{1}{a} \sum_{i=1}^{a} \mu_{ij} \qquad \text{and} \qquad \text{j = 1,2, \ldots,b}$$

- the interaction effect,$(\alpha\beta)_{ij}$

$$(\alpha\beta)_{ij} = \mu_{ij} - (\mu_{ij} + \alpha_i + \beta j) = \mu_{ij} - \mu_{i.} - \mu_{.j} + \mu_{..} \text{where} \qquad \text{i = 1,2, \ldots,a and} \qquad \text{j = 1,2, \ldots,b}$$

Translating these equations, the main effect is defined as the effect of x1 after averaging over all levels of x2, and vice versa. If there exists an interaction then, the effect of factor x1 is dependent on the level of factor x2, or vice versa.

Each of the quantities is combined in a statistical model:

$$Y_{ijk} = \mu_{..} + \alpha_i + \beta_j + (\alpha\beta)_{ij} + \varepsilon_{ijk}$$

In our example design, k=1 replication.

This model provides estimates of each of the above quantities. The final term in the model ε is an approximation of the error which is given by the `residuals` (whats left over after fitting the model).

It should be noted that this design constitutes an non-replicated (k=1) experiment. If we perform replications then each individual 'ij' response will be an estimate of the mean for that combination. Subsequently, the row mean, column mean and overall mean would be an average of the mean response for each combination i.e. $\overline{\mu}$.

Replications, when permissible, should always be carried out allowing standard errors (or estimated standard deviations) to be calculated, providing a more secure analysis model. Performing replications allows standard errors(or standard deviation effects) to be calculated but if experiments are non-replicated then we have to construct probability plots to estimate significant effects. If in the non-replicated situation, none of the factors were deemed to be significant then each observation would conform to being a random sample from a Normal distribution.

DESIGN OF EXPERIMENT

RUN	x1	x2	x3	Y(response)
1	-	-	+	Y1
2	+	-	-	Y2
3	-	+	-	Y3
4	+	+	+	Y4

L0 = (Y1+Y2+Y3+Y4)/4 -> mean + (123)
L1 = (-Y1+Y2-Y3+Y4)/ -> (1) + (23)
L2 = (-Y1-Y2+Y3+Y4)/4 -> (2) + (13)
L3 = (Y1-Y2-Y3+Y4)/4 -> (3) + (12)

6.4 Fractional factorial experiments

What happens when we have constraints placed on the number of experimental runs we can perform or when $k \to \infty$? The answer is to construct a fractional factorial design matrix with 2^{k-p} experimental runs i.e. half fractional factorial when p=1. Obviously in this design certain information has to be sacrificed as not all factor combinations are analysed.

Let us proceed to interpret how a basic, fractional factorial experiment, design matrix is constructed, see Figure 6.3.

The design includes 3 factors, each with an associated 2 levels. If a full factorial experiment was carried out then we would have $2^3 = 8$ experimental runs and therefore we must ask;What information are we disregarding and what relationships are we analysing in a fractional design ??

The straight forward and logical answer is to sacrifice information on higher order interactions where in most cases, interactions of order 3 and above can be judged negligible. To generate each column in the fractional design matrix, we first write down a complete (full) factorial design in any 2 factors and then associate the interaction with the remaining factor where ideally main effects are *confounded* with the highest possible interactions.

A full 2^2 is constructed for factors x1 and x2, with x3=x1x2. If we let I be a column of +'s clearly,

$I = x1x1 = x2x2 = x3x3$

Now $x3 = x1x2 \quad \Rightarrow x3x3 = x1x2x3$

I=x1x2x3

This is defined to be the generator for the 2^{3-1} design and from this we can determine the other confounding patterns.

$Ix1 = x1(x1x2x3)$ i.e. x1=x2x3

$Ix2 = x2(x1x2x3)$ i.e. x2=x1x3 $Ix3 = x3(x1x2x3)$ i.e. x3=x1x2

Unfortunately this example incorporates *aliasing*, where it is difficult to distinguish between main effects and interactions and therefore fractional factorial designs are only recommended when the number of factors is significantly large.

From the design, Figure 6.3, L0 corresponds to the overall mean plus the three-factor interaction, L1 corresponds to the main effect of factor 1 plus the interaction between factors 2 and 3 respectively etc.

This design is said to have *resolution* IV i.e. (1+3=4) and (2+2=4). The higher the resolution the better the better the confounding relationships. Designs which incorporate small fractions (e.g. $1/16$ of the full 2^8 design) will more than likely *confound* main effects with low-order interactions and therefore further experimentation may be necessary e.g. *folding over* (changing the signs of each factor in each column) the original design to obtain another fraction. In most instances where main effects are combined with higher order interactions, the design will provide un-confounded estimates of the main effects, provided higher order interactions are deemed negligible.

The initial designs in this experiment incorporate 2^{7-3} and 2^{8-4} designs. It was not felt necessary to explain the construction of these complex designs. Anyone wishing information on higher fractional designs should refer [G.E.P.Box, 1978].

6.5 Pro Forma for analysing PF

The analysis performed for each application in this project can be categorised into two main sections:

1. Fractional Factorial Screening Experiment: Starting block for analysis. An intial screening, fractional design matrix is constructed, incorporating a number of factors which fit into the 2-level categorie. Each experiment is performed once for each instrumented PF operation within each test application. If performing experiments during the working hours the order each experimental run is carried out in random order thus reducing variability from extraneous sources such as other processor loads. Using the statistical package Minitab the following information can be extracted:

    - We have an non-replicated design, therefore using *normal* probability plots we can estimate which factors appear to be significant.
    - The response variable is average time therefore we repeat the experiment for the standard deviation to check for any discrepancies.

2. One Factor Analysis: Look at factors with higher levels which require more in-depth analysis such as client/server ratio and local/remote disk. Use Minitab to construct Analysis of Variance tables and dotplots/boxplots to compare each treatment.

    Dotplots and boxplots provide:

    - how observations vary around the treatment(level) group mean
    - how each treatment(level) group mean differs

    ANOVA tables provide:

    - estimates of variance
    - F-tests for testing the null hypothesis that all treatment(level) means are the same

7 CONCLUSIONS

7.1 Introduction

The normal advantages associated with constructing FFD's has somewhat been lost due due to certain, problematic factors, see H.5. Despite the fact the author has attempted to provide a sound framework for analysis, the following conclusions do not attempt to make any profound statements on overall I/O performance mainly due to time constraints, configuration problems and most of all, lack of working within the UNIX environment. It must be stressed that PF has not been tested to its fullest capabilities as originally planned, only specific configurations have been carried out and therefore any comments on I/O bandwidth etc. cannot be deemed conclusive. It is expected that the majority of the configuration problems are due to applications supplying in-appropriate I/O Hints, see [Clarke L., 1993]. These problems are not thought to be PF related but problems within the test applications which attempt to collate results for numerous configurations using runtime parameters. Keeping a level of configuration control has been difficult mainly due to inefficient error messages in certain experimental runs. When defining configurations it is advisable to be explicit, as relying on defaults in certain situations can be mis-leading.

Unfortunately, the Numerical application has not been correctly tested due to unforseen errors. The application has been written but requires testing.

7.2 Format of MINITAB Outfiles and Extracting Information

#Comments are provided in each outfile with *#operation ID* notifying which operation is under analysis.

For example, the first outfile page provided in A has the Database FFD experiment for the operation ID 0 (pfexport) and operation ID 1 (pfopenfile). We note the effects given and also the plotted values of NSCORES (quantiles from standard normal distribution) and the estimated effects. If we have no significant factors then each point will lie on a straight line plotted through the origin(0,0).

In this instance *pfexport* does not appear to be significantly effected by any of the factors but in the case of *pfopenfile*, FACTOR D (split/single) appears to be significant and has a negative effect on the response variable, average time. If we are looking to reduce overall time then we would have single partitions for optimum performance in this instance, i.e. level (-).

To analyse factors such as client/server ratio and local/remote disk, experimental runs have been sampled from the larger experimental design. This is acceptable for a more economical approach as long as the assumptions are fully taken into consideration.

Referring to B we have the Database client/server ratio. Eight runs have been sampled from the FFD matrix. Each run is performed for varying client/server ratios. For *pfexport* our dotplots suggest that I/O performance is improved by increasing the server/client ratio.Our dotplots clearly show that with the 6/1 server/client ratio the overall time for *pfexport* is significantly less compared to the other scenarios(5/2,3/4,2/5...servers/clients). Our one-way ANOVA table compares the means for each ratio and tests the null hypothesis that each scenario mean is the same. The F-statistic, ratio of mean squares(factor) to mean squares(error), can be tested using statistical tables to test wether or not we can reject the null hypothesis that all factor(server/client scenarios) means are the same, see [G.E.P.Box, 1978]. In this instance we can reject the null hypothesis and conclude that that the means for each client/server ratio differ.

The confidence intervals provide a graphical interpretation of how these population means differ. Again clearly the bottleneck situation, 2/5 (servers/clients), slows the overall completion time for *pfexport*.

Finally a plot of residuals against group averages is provided. If there is large variance for the residuals in each group we should consider a transformation of data as there has more than likely been interference in the experiment from extraneous sources e.g. in the case of testing PF, other processor loads.

7.3 Filter/Database and General Results

For both *filter* and *database*, a 2^{7-4} fractional design has been constructed with the following factors(where(-)(+) denotes levels):

- x1=fixed/variable sized atoms (+)(-)
- x2=serial filesize (600)(-) (2000)(+)
- x3=maximum atom size (16)(-) (32)(+)
- x4=split/single (+)(-)
- x5=compute iterations (1)(-) (100)(+)
- x6=array size(no. of atoms to be read) (60)(-) (600)(+)
- x7=local/remote server access(for clients) (remote)(-) (local)(+)

A list of assumptions about the unfortunately simplistic model are as follows:

- the PFD is set at PARTITION
- each parallel file segment is stored in the local disk mounted /tmp
- one to one client/server ratio(3 and 3)
- two sub-groups (2 reading,1 writing) or single partition
- all servers access all disks
- independent PFAM

Each of the 16 runs was performed for each of the timed functions, a list of these functions and ID's are as follows:

- pfexport ID 0
- pfopenfile ID 1
- pfreadatom ID 2
- pfwriteatom ID 3
- pfclosefile ID 4
- serveridletime ID 5
- computetime ID 6

Database FFD:

1. **pfexport:** Nothing significant.
2. **pfopenfile:** Possibly split/single server partitions.
3. **pfreadatom:** Nothing of great significance for average time, comparing the standard deviation transformation(single-to-noise ratio) we not that the local/remote server access appears significant. This is because some factors effect the mean and some the variance.
4. **pfwriteatom:** Again when analysing the single-to-noise ratio we see that the local/remote server access factor appears significant.
5. **pfclosefile:** The array size and local/remote server access have significant effects on the overall time for closing the file. This implies we would set array size at a low level and configure clients with local servers to reduce overall I/O time.
6. **computetime:** Logically (and thankfully!) the maximum atom size effects the overall compute time per atom.

DATABASE CLIENT/SERVER ratio:

Increasing the server/client ratio improves I/O performance for each of the timed operations as expected, see B.

DATABASE LOCAL/REMOTE disk:

For all operations local disks for parallel file segments is considerably quicker than storing disks on remote disks as expected, see C.

FILTER FFD:

1. pfexport: Nothing in this design causing a stir.
2. pfopenfile: The single/split server partitions appear to have a bearing on the execution time along with file size which appears logical. Looking at the signal-to-noise ratio we can deduce that the file size is having a significant effect on the overall time. (Low file size for reduced operation time.)

3. pfreadatom: The file size appears to be significant against average time and the signal-to-noise ratio.
4. pfwriteatom: The local/remote server access is significant and we would set it to the low level(-) to reduce atom transfer time.
5. pfclosefile: The array size appears to be having a significant effect.
6. computetime: It appears that most of that the number of compute iterations is significant but is a rather dubious answer (suspect extraneous sources!).

FILTER CLIENT/SERVER ratio:

Again increasing the server/client ratio improves I/O performance for each of the timed operations as expected, see E.

FILTER LOCAL/REMOTE disk:

For most operations local disks for parallel file segments is considerably quicker than storing disks on remote disks as expected, see F. However the reading and writing operations take longer to perform when accessing local disks, which suggests interference from other processor loads in these experiments.

8 Project Status

Most of the features offered by PF are in place despite the problems presented in H.5. Unfortunately these features were not included in any designs and thus experiments still need to be performed including *working* PFD's and PFAM's as these features are presented as major contributors to overall I/O performance, in [Clarke L., 1993]. The Numerical application has had to be run again due to a major mistake in the design. It is suggested that the factor 'fixed/variable sized atoms' is swapped for array dimensions and a FFD similar to FILTER/DATABASE is performed.

9 Acknowledgements

First of all I would like to thank everyone associated with the SSP for giving me this opportunity to gain priceless computational experience that I would not otherwise have had.

I would like to thank Colin Brough for his immaculate organisation of the SSP and for his advice and patience.

Despite the fact most of the results produced in this project are mainly arbitrary to the PUL team, the experience of working with such an intellectually rewarding and well structured project has provided me with invaluable confidence and ability for any future career opportunities. Therefore, I would also like to say a special thanks to the project supervisors, Kenneth Cameron(EPCC) and Simon Chapple(EPCC), for there guidance and patience this summer .

10 Appendix A

A DATABASE FFD

Oct 6 1994 16:51:43 **datffd0.lis** Page 1

```
MTB > #database fractional factorial design
MTB > print c1-c7


 ROW  fixvar  filesize  maxatom  splitsin  comiter  array  locremsv

   1      -1        -1       -1        -1       -1     -1        -1
   2       1        -1       -1        -1        1     -1         1
   3      -1         1       -1        -1        1      1        -1
   4       1         1       -1        -1       -1      1         1
   5      -1        -1        1        -1        1      1         1
   6       1        -1        1        -1       -1      1        -1
   7      -1         1        1        -1       -1     -1         1
   8       1         1        1        -1        1     -1        -1
   9      -1        -1       -1         1       -1      1         1
  10       1        -1       -1         1        1      1        -1
  11      -1         1       -1         1        1     -1         1
  12       1         1       -1         1       -1     -1        -1
  13      -1        -1        1         1        1     -1        -1
  14       1        -1        1         1       -1     -1         1
  15      -1         1        1         1       -1      1        -1
  16       1         1        1         1        1      1         1

NOTE *** Data window was used to change the worksheet
MTB > #operation ID 0
MTB > ffactorial avtime0=(fixvar-locremsv)2;
SUBC> eplot;
SUBC> effects c32.

Alias Information for Terms in the Model.
Totally confounded terms were removed from the analysis

fixvar*filesize + maxatom*comiter + array*locremsv
fixvar*maxatom + filesize*comiter + splitsin*locremsv
fixvar*splitsin + maxatom*locremsv + comiter*array
fixvar*comiter + filesize*maxatom + splitsin*array
fixvar*array + filesize*locremsv + splitsin*comiter
fixvar*locremsv + filesize*array + maxatom*splitsin
filesize*splitsin + maxatom*array + comiter*locremsv

Estimated Effects and Coefficients for avtime0

Term                Effect     Coef  Std Coef t-value      P
Constant                     2.0146    0.2139    9.42  0.067
fixvar             -0.1791  -0.0896    0.2139   -0.42  0.748
filesize            0.0021   0.0010    0.2139    0.00  0.997
maxatom             0.1439   0.0719    0.2139    0.34  0.793
splitsin           -0.1248  -0.0624    0.2139   -0.29  0.819
comiter            -0.2050  -0.1025    0.2139   -0.48  0.715
array               0.5097   0.2548    0.2139    1.19  0.444
locremsv           -0.2927  -0.1463    0.2139   -0.68  0.618
fixvar*filesize    -0.2864  -0.1432    0.2139   -0.67  0.624
fixvar*maxatom     -0.3774  -0.1887    0.2139   -0.88  0.540
fixvar*splitsin     0.0223   0.0112    0.2139    0.05  0.967
fixvar*comiter      0.3750   0.1875    0.2139    0.88  0.542
fixvar*array        0.2875   0.1438    0.2139    0.67  0.623
fixvar*locremsv     0.1391   0.0696    0.2139    0.33  0.800
filesize*splitsin   0.7493   0.3747    0.2139    1.75  0.330



Analysis of Variance for avtime0

Source                DF      Seq SS     Adj SS     Adj MS      F      P
Main Effects           7      1.8233     1.8233     0.2605   0.36  0.862
2-Way Interactions     7      4.1163     4.1163     0.5880   0.80  0.699
Residual Error         1      0.7318     0.7318     0.7318
Total                 15      6.6714


 Nscores -
```

Oct 6 1994 16:51:43 **datffd0.lis** Page 2

```
           -                                                  * BD
           -
        1.2+                                        *    F
           -                                   *     AE
           -                                *     AF
           -                          *     C
           -                          *     AG
        0.0+                    **     B,AD
           -               *     D
           -             *     A
           -            *     E
           -         *     AB
       -1.2+        *     G
           -
           -   *     AC
           -
             ------+---------+---------+---------+---------+Effects
                -0.25      0.00      0.25      0.50      0.75

A = fixvar    B = filesize  C = maxatom   D = splitsin  E = comiter
F = array     G = locremsv
```

1

Oct 6 1994 17:29:18 **datffd1.lis** Page 1

```
MTB > #operation ID 1
MTB > ffactorial avtime1=(fixvar-locremsv)2;
SUBC> eplot;
SUBC> effects c32.

Alias Information for Terms in the Model.
Totally confounded terms were removed from the analysis

fixvar*filesize + maxatom*comiter + array*locremsv
fixvar*maxatom + filesize*comiter + splitsin*locremsv
fixvar*splitsin + maxatom*locremsv + comiter*array
fixvar*comiter + filesize*maxatom + splitsin*array
fixvar*array + filesize*locremsv + splitsin*comiter
fixvar*locremsv + filesize*array + maxatom*splitsin
filesize*splitsin + maxatom*array + comiter*locremsv



Estimated Effects and Coefficients for avtime1

Term                Effect     Coef  Std Coef t-value      P
Constant                     6.7416    0.2666   25.29  0.025
fixvar              0.2134   0.1067    0.2666    0.40  0.758
filesize           -0.0650  -0.0325    0.2666   -0.12  0.923
maxatom            -0.1336  -0.0668    0.2666   -0.25  0.844
splitsin           -0.3858  -0.1929    0.2666   -0.72  0.601
comiter            -0.2363  -0.1181    0.2666   -0.44  0.734
array               0.5207   0.2604    0.2666    0.98  0.507
locremsv            0.2319   0.1160    0.2666    0.44  0.739
fixvar*filesize     0.2068   0.1034    0.2666    0.39  0.764
fixvar*maxatom     -0.3359  -0.1679    0.2666   -0.63  0.642
fixvar*splitsin    -0.2034  -0.1017    0.2666   -0.38  0.768
fixvar*comiter      0.0244   0.0122    0.2666    0.05  0.971
fixvar*array        0.7068   0.3534    0.2666    1.33  0.411
fixvar*locremsv     0.2473   0.1236    0.2666    0.46  0.724
filesize*splitsin  -0.0820  -0.0410    0.2666   -0.15  0.903

Analysis of Variance for avtime1

Source                DF      Seq SS     Adj SS     Adj MS      F      P
Main Effects           7       2.389      2.389     0.3413   0.30  0.889
2-Way Interactions     7       3.060      3.060     0.4371   0.38  0.849
Residual Error         1       1.137      1.137     1.1368
Total                 15       6.586


 Nscores -
        -                                          *   AF
        -
     1.2+                                   *    F
        -                        *    AG
        -                       *    G
        -                       *    A
        -                      *    AB
     0.0+             *   *    B,AE
        -             *    BD
        -            *    C
        -          *    AD
        -         *    E
    -1.2+     *    AC
        -
        -   *    D
        -
          ------+---------+---------+---------+---------+Effects
             -0.25      0.00      0.25      0.50      0.75

A = fixvar    B = filesize  C = maxatom   D = splitsin  E = comiter
F = array     G = locremsv
```

1

Oct 6 1994 17:34:40 **datffd2.lis** Page 1

```
MTB > #operation ID 2
MTB > ffactorial avtime2=(fixvar-locremsv)2;
SUBC> eplot;
SUBC> effects c32.

Alias Information for Terms in the Model.
Totally confounded terms were removed from the analysis

fixvar*filesize + maxatom*comiter + array*locremsv
fixvar*maxatom + filesize*comiter + splitsin*locremsv
fixvar*splitsin + maxatom*locremsv + comiter*array
fixvar*comiter + filesize*maxatom + splitsin*array
fixvar*array + filesize*locremsv + splitsin*comiter
fixvar*locremsv + filesize*array + maxatom*splitsin
filesize*splitsin + maxatom*array + comiter*locremsv



Estimated Effects and Coefficients for avtime2

Term                 Effect      Coef  Std Coef t-value      P
Constant                      1.07486   0.01020  105.35  0.006
fixvar             -0.01428  -0.00714   0.01020   -0.70  0.611
filesize            0.01108   0.00554   0.01020    0.54  0.683
maxatom             0.01800   0.00900   0.01020    0.88  0.540
splitsin            0.02443   0.01222   0.01020    1.20  0.443
comiter            -0.04878  -0.02439   0.01020   -2.39  0.252
array              -0.06709  -0.03354   0.01020   -3.29  0.188
locremsv            0.04727   0.02363   0.01020    2.32  0.259
fixvar*filesize    -0.00605  -0.00302   0.01020   -0.30  0.817
fixvar*maxatom      0.03274   0.01637   0.01020    1.60  0.355
fixvar*splitsin    -0.01393  -0.00697   0.01020   -0.68  0.619
fixvar*comiter     -0.05158  -0.02579   0.01020   -2.53  0.240
fixvar*array        0.02871   0.01436   0.01020    1.41  0.393
fixvar*locremsv    -0.01890  -0.00945   0.01020   -0.93  0.524
filesize*splitsin  -0.02204  -0.01102   0.01020   -1.08  0.476

Analysis of Variance for avtime2

Source               DF      Seq SS     Adj SS     Adj MS      F      P
Main Effects          7    0.041452   0.041452   0.005922   3.56  0.388
2-Way Interactions    7    0.022526   0.022526   0.003218   1.93  0.505
Residual Error        1    0.001666   0.001666   0.001666
Total                15    0.065643


  Nscores -
          -                                      *   G
          -
       1.2+                                 *    AC
          -                                *    AF
          -                              *    D
          -                            *    C
          -                          *    B
       0.0+                 *  *    AD,AB
          -                 *    A
          -                *    AG
          -               *    BD
          -          *    E
      -1.2+         *    AE
          -
          -     *    F
          -
            --------+---------+---------+---------+--------Effects
               -0.060    -0.030     0.000     0.030

A = fixvar    B = filesize  C = maxatom   D = splitsin  E = comiter
F = array     G = locremsv
```

Oct 6 1994 17:37:21 **datffd2s.out** Page 1

1

```
MTB > #compare standard deviation for operation ID 2
MTB > let c33=20*logten(c12/c13)
MTB > ffactorial c33=(fixvar-locremsv)2;
SUBC> eplot;
SUBC> effects c32.

Alias Information for Terms in the Model.
Totally confounded terms were removed from the analysis



fixvar*filesize + maxatom*comiter + array*locremsv
fixvar*maxatom + filesize*comiter + splitsin*locremsv
fixvar*splitsin + maxatom*locremsv + comiter*array
fixvar*comiter + filesize*maxatom + splitsin*array
fixvar*array + filesize*locremsv + splitsin*comiter
fixvar*locremsv + filesize*array + maxatom*splitsin
filesize*splitsin + maxatom*array + comiter*locremsv

Estimated Effects and Coefficients for C33

Term                 Effect      Coef  Std Coef t-value      P
Constant                        5.301    0.4111   12.89  0.049
fixvar                1.693     0.846    0.4111    2.06  0.288
filesize              5.435     2.717    0.4111    6.61  0.096
maxatom               1.052     0.526    0.4111    1.28  0.422
splitsin             -0.743    -0.372    0.4111   -0.90  0.532
comiter               1.171     0.585    0.4111    1.42  0.390
array                -4.828    -2.414    0.4111   -5.87  0.107
locremsv             -7.145    -3.572    0.4111   -8.69  0.073
fixvar*filesize       1.424     0.712    0.4111    1.73  0.333
fixvar*maxatom        0.084     0.042    0.4111    0.10  0.935
fixvar*splitsin       0.165     0.083    0.4111    0.20  0.874
fixvar*comiter        1.248     0.624    0.4111    1.52  0.371
fixvar*array         -2.256    -1.128    0.4111   -2.74  0.223
fixvar*locremsv      -1.536    -0.768    0.4111   -1.87  0.313
filesize*splitsin    -0.059    -0.029    0.4111   -0.07  0.954

Analysis of Variance for C33

Source               DF      Seq SS     Adj SS     Adj MS      F      P
Main Effects          7     439.173    439.173     62.739  23.20  0.159
2-Way Interactions    7      44.282     44.282      6.326   2.34  0.466
Residual Error        1       2.704      2.704      2.704
Total                15     486.159


  Nscores -
          -                                     *   B
          -
       1.2+                           *    A
          -                          *    AB
          -                         *    AE
          -                         *    E
          -                         *    C
       0.0+                     **    AC,AD
          -                     *    BD
          -                   *    D
          -                *    AG
          -             *    AF
      -1.2+         *    F
          -
          -  *    G
          -
            ------+---------+---------+---------+---------+Effects
               -6.0      -3.0       0.0       3.0       6.0

A = fixvar    B = filesize  C = maxatom   D = splitsin  E = comiter
F = array     G = locremsv
```

1

Oct 6 1994 17:48:24 **datffd3a.lis** Page 1

```
MTB > #operation ID 3
MTB > ffactorial avtime3=(fixvar-locrem)2;
* ERROR * Illegal variable name or undefined name or
          improper use of quote




MTB > ffactorial avtime3=(fixvar-locremsv)2;
SUBC> eplot;
SUBC> effects c32.

Alias Information for Terms in the Model.
Totally confounded terms were removed from the analysis

fixvar*filesize + maxatom*comiter + array*locremsv
fixvar*maxatom + filesize*comiter + splitsin*locremsv
fixvar*splitsin + maxatom*locremsv + comiter*array
fixvar*comiter + filesize*maxatom + splitsin*array
fixvar*array + filesize*locremsv + splitsin*comiter
fixvar*locremsv + filesize*array + maxatom*splitsin
filesize*splitsin + maxatom*array + comiter*locremsv

Estimated Effects and Coefficients for avtime3

Term                  Effect      Coef  Std Coef t-value      P
Constant                       1.12248   0.01282   87.58  0.007
fixvar              -0.03033  -0.01517   0.01282   -1.18  0.447
filesize             0.02757   0.01379   0.01282    1.08  0.477
maxatom             -0.03824  -0.01912   0.01282   -1.49  0.376
splitsin            -0.01131  -0.00566   0.01282   -0.44  0.735
comiter              0.02624   0.01312   0.01282    1.02  0.493
array                0.09289   0.04644   0.01282    3.62  0.171
locremsv             0.04665   0.02333   0.01282    1.82  0.320
fixvar*filesize      0.08011   0.04006   0.01282    3.13  0.197
fixvar*maxatom      -0.02142  -0.01071   0.01282   -0.84  0.557
fixvar*splitsin     -0.07428  -0.03714   0.01282   -2.90  0.212
fixvar*comiter       0.01160   0.00580   0.01282    0.45  0.729
fixvar*array         0.01897   0.00948   0.01282    0.74  0.594
fixvar*locremsv      0.01939   0.00969   0.01282    0.76  0.588
filesize*splitsin    0.02654   0.01327   0.01282    1.04  0.489

Analysis of Variance for avtime3

Source                DF      Seq SS     Adj SS     Adj MS      F      P
Main Effects           7    0.059054   0.059054   0.008436   3.21  0.406
2-Way Interactions     7    0.055876   0.055876   0.007982   3.04  0.416
Residual Error         1    0.002628   0.002628   0.002628
Total                 15    0.117559




 Nscores -
        -                                       *  F
        -
     1.2+                                    *    AB
        -                            *    G
        -                       *    B
        -                       *    BD
        -                       *    E
     0.0+                     2    AF,AG
        -                    *    AE
        -               *    D
        -             *    AC
        -          *    A
    -1.2+        *    C
        -
        -    *    AD
        -
          --+---------+---------+---------+---------+----Effects
```

Oct 6 1994 17:48:24 **datffd3a.lis** Page 2

```
         -0.080    -0.040     0.000     0.040     0.080

A = fixvar    B = filesize  C = maxatom   D = splitsin  E = comiter
F = array     G = locremsv
```

Oct 6 1994 17:50:04 **datffd3s.lis** Page 1

```
MTB > #compare standard deviation for operation ID 3
MTB > let c33=20*logten(c14/c15)
MTB > ffactorial c33=(fixvar-locremsv)2;
SUBC> eplot;
SUBC> effects c32.

Alias Information for Terms in the Model.
Totally confounded terms were removed from the analysis

fixvar*filesize + maxatom*comiter + array*locremsv
fixvar*maxatom + filesize*comiter + splitsin*locremsv
fixvar*splitsin + maxatom*locremsv + comiter*array
fixvar*comiter + filesize*maxatom + splitsin*array
fixvar*array + filesize*locremsv + splitsin*comiter
fixvar*locremsv + filesize*array + maxatom*splitsin
filesize*splitsin + maxatom*array + comiter*locremsv

Estimated Effects and Coefficients for C33

Term                  Effect      Coef  Std Coef t-value      P
Constant                         4.739    0.1816   26.09  0.024
fixvar                 1.781     0.890    0.1816    4.90  0.128
filesize               5.297     2.648    0.1816   14.58  0.044
maxatom                0.193     0.097    0.1816    0.53  0.688
splitsin              -0.216    -0.108    0.1816   -0.59  0.659
comiter                0.072     0.036    0.1816    0.20  0.876
array                 -3.837    -1.918    0.1816  -10.56  0.060
locremsv              -5.917    -2.958    0.1816  -16.29  0.039
fixvar*filesize        0.746     0.373    0.1816    2.05  0.289
fixvar*maxatom        -0.796    -0.398    0.1816   -2.19  0.273
fixvar*splitsin        1.818     0.909    0.1816    5.00  0.126
fixvar*comiter        -0.533    -0.266    0.1816   -1.47  0.381
fixvar*array          -1.958    -0.979    0.1816   -5.39  0.117
fixvar*locremsv       -0.944    -0.472    0.1816   -2.60  0.234
filesize*splitsin     -0.129    -0.064    0.1816   -0.35  0.783



Analysis of Variance for C33

Source                DF      Seq SS     Adj SS     Adj MS      F      P
Main Effects           7     324.165    324.165    46.3093  87.72  0.082
2-Way Interactions     7      38.074     38.074     5.4392  10.30  0.236
Residual Error         1       0.528      0.528     0.5279
Total                 15     362.767


 Nscores -
        -                                      *  B
        -
     1.2+                        *    AD
        -                        *    A
        -                    *    AB
        -                  *    C
        -                 *    E
     0.0+                2    D,BD
        -               *    AE
        -              *    AC
        -             *    AG
        -         *    AF
    -1.2+      *    F
        -
        - *    G
        -
          ----+---------+---------+---------+---------+--Effects
             -5.0      -2.5       0.0       2.5       5.0

A = fixvar    B = filesize  C = maxatom   D = splitsin  E = comiter
F = array     G = locremsv
```

Oct 6 1994 17:50:04 **datffd3s.lis** Page 2

1

1

Oct 6 1994 18:03:53 **datffd4.lis** Page 1

```
MTB > #operation ID 4
MTB > ffactorial avtime4=(fixvar-locremsv)2;
SUBC> eplot;
SUBC> effects c32.

Alias Information for Terms in the Model.
Totally confounded terms were removed from the analysis

fixvar*filesize + maxatom*comiter + array*locremsv
fixvar*maxatom + filesize*comiter + splitsin*locremsv
fixvar*splitsin + maxatom*locremsv + comiter*array
fixvar*comiter + filesize*maxatom + splitsin*array
fixvar*array + filesize*locremsv + splitsin*comiter
fixvar*locremsv + filesize*array + maxatom*splitsin
filesize*splitsin + maxatom*array + comiter*locremsv

Estimated Effects and Coefficients for avtime4

Term                  Effect      Coef  Std Coef t-value      P
Constant                         16.05    0.1078  148.82  0.004
fixvar                 -2.47     -1.24    0.1078  -11.45  0.055
filesize               -1.19     -0.59    0.1078   -5.51  0.114
maxatom                 0.86      0.43    0.1078    4.01  0.156
splitsin                0.64      0.32    0.1078    2.96  0.208
comiter                -0.29     -0.15    0.1078   -1.35  0.406
array                  27.71     13.86    0.1078  128.51  0.005
locremsv              -20.46    -10.23    0.1078  -94.88  0.007
fixvar*filesize       -20.73    -10.37    0.1078  -96.15  0.007
fixvar*maxatom         -0.63     -0.32    0.1078   -2.93  0.210
fixvar*splitsin        -0.22     -0.11    0.1078   -1.01  0.497
fixvar*comiter          0.56      0.28    0.1078    2.60  0.234
fixvar*array           -1.78     -0.89    0.1078   -8.26  0.077
fixvar*locremsv        -1.27     -0.63    0.1078   -5.87  0.107
filesize*splitsin       0.55      0.27    0.1078    2.54  0.239

Analysis of Variance for avtime4

Source                DF      Seq SS     Adj SS     Adj MS      F      P
Main Effects           7     4781.64    4781.64    683.091 4E+03  0.013
2-Way Interactions     7     1742.97    1742.97    248.996 1E+03  0.021
Residual Error         1        0.19       0.19      0.186
Total                 15     6524.80




 Nscores -
         -                                            *    F
         -
      1.2+                      *    C
         -                      *    D
         -                     *    AE
         -                     *    BD
         -                     *    AD
      0.0+                    **    AC,E
         -                    *    B
         -                    *    AG
         -                    *    AF
         -                   *    A
     -1.2+    *    G
         -
         -    *    AB
         -
           +---------+---------+---------+---------+------Effects
         -24       -12         0        12        24

A = fixvar    B = filesize  C = maxatom   D = splitsin  E = comiter
F = array     G = locremsv
```

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1

```
MTB > #operation ID 6
MTB > ffactorial avtime6=(fixvar-locremsv)2;
SUBC> eplot;
SUBC> effects c32.

Alias Information for Terms in the Model.
Totally confounded terms were removed from the analysis

fixvar*filesize + maxatom*comiter + array*locremsv
fixvar*maxatom + filesize*comiter + splitsin*locremsv
fixvar*splitsin + maxatom*locremsv + comiter*array
fixvar*comiter + filesize*maxatom + splitsin*array
fixvar*array + filesize*locremsv + splitsin*comiter
fixvar*locremsv + filesize*array + maxatom*splitsin
filesize*splitsin + maxatom*array + comiter*locremsv

Estimated Effects and Coefficients for avtime6

Term                  Effect      Coef  Std Coef t-value      P
Constant                      0.000562  0.000004  152.29  0.004
fixvar              0.000055  0.000027  0.000004    7.41  0.085
filesize           -0.000003 -0.000002  0.000004   -0.46  0.727
maxatom             0.000087  0.000044  0.000004   11.85  0.054
splitsin           -0.000004 -0.000002  0.000004   -0.49  0.709
comiter            -0.000006 -0.000003  0.000004   -0.76  0.585
array              -0.000001 -0.000000  0.000004   -0.12  0.925
locremsv           -0.000013 -0.000006  0.000004   -1.75  0.331
fixvar*filesize    -0.000011 -0.000006  0.000004   -1.54  0.366
fixvar*maxatom      0.000004  0.000002  0.000004    0.59  0.659
fixvar*splitsin    -0.000004 -0.000002  0.000004   -0.56  0.675
fixvar*comiter      0.000003  0.000001  0.000004    0.39  0.763
fixvar*array        0.000030  0.000015  0.000004    4.02  0.155
fixvar*locremsv    -0.000018 -0.000009  0.000004   -2.42  0.249
filesize*splitsin  -0.000014 -0.000007  0.000004   -1.85  0.316



Analysis of Variance for avtime6

Source                DF      Seq SS     Adj SS     Adj MS      F      P
Main Effects           7  0.00000004 0.00000004 0.00000001  28.47  0.143
2-Way Interactions     7  0.00000001 0.00000001 0.00000000   4.09  0.364
Residual Error         1  0.00000000 0.00000000 0.00000000
Total                 15  0.00000005


 Nscores -
         -                                              *  C
         -
      1.2+                                  *    A
         -                       *    AF
         -             *    AC
         -            *    AE
         -           *    F
      0.0+          2    B,D
         -         *    AD
         -         *    E
         -      *    AB
         -      *    G
     -1.2+      *    BD
         -
         -    *    AG
         -
           +---------+---------+---------+---------+------Effects
    -2.5E-05  0.000000  0.000025  0.000050  0.000075

A = fixvar    B = filesize  C = maxatom   D = splitsin  E = comiter
F = array     G = locremsv
```

1

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```
MTB > compare standard deviation for operation ID 6
MTB > let c33=20*logten(c18/c19)
MTB > ffactorial c33=(fixvar-locremsv)2;
SUBC> eplot;
SUBC> effects c32.

Alias Information for Terms in the Model.
Totally confounded terms were removed from the analysis

fixvar*filesize + maxatom*comiter + array*locremsv
fixvar*maxatom + filesize*comiter + splitsin*locremsv
fixvar*splitsin + maxatom*locremsv + comiter*array
fixvar*comiter + filesize*maxatom + splitsin*array
fixvar*array + filesize*locremsv + splitsin*comiter
fixvar*locremsv + filesize*array + maxatom*splitsin
filesize*splitsin + maxatom*array + comiter*locremsv



Estimated Effects and Coefficients for C33

Term                 Effect      Coef  Std Coef t-value      P
Constant                        0.433    0.8541    0.51  0.701
fixvar                6.696     3.348    0.8541    3.92  0.159
filesize              0.969     0.485    0.8541    0.57  0.671
maxatom              -4.430    -2.215    0.8541   -2.59  0.234
splitsin             -2.476    -1.238    0.8541   -1.45  0.384
comiter               1.282     0.641    0.8541    0.75  0.590
array               -10.297    -5.148    0.8541   -6.03  0.105
locremsv              6.731     3.366    0.8541    3.94  0.158
fixvar*filesize      -0.179    -0.089    0.8541   -0.10  0.934
fixvar*maxatom        4.672     2.336    0.8541    2.74  0.223
fixvar*splitsin      -0.115    -0.057    0.8541   -0.07  0.957
fixvar*comiter        0.713     0.356    0.8541    0.42  0.748
fixvar*array         -4.353    -2.177    0.8541   -2.55  0.238
fixvar*locremsv       1.618     0.809    0.8541    0.95  0.517
filesize*splitsin     1.232     0.616    0.8541    0.72  0.602

Analysis of Variance for C33

Source               DF      Seq SS     Adj SS     Adj MS      F      P
Main Effects          7      898.02     898.02     128.29  10.99  0.228
2-Way Interactions    7      181.88     181.88      25.98   2.23  0.476
Residual Error        1       11.67      11.67      11.67
Total                15     1091.57


 Nscores -
         -                                              *  G
         -
      1.2+                                              *  A
         -                                         *    AC
         -                                 *    AG
         -                                *    E
         -                                *    BD
      0.0+                               2    B,AE
         -                             *    AD
         -                             *    AB
         -                       *    D
         -                  *    AF
     -1.2+                  *    C
         -
         -   *    F
         -
           --------+---------+---------+---------+--------Effects
                -8.0      -4.0       0.0       4.0

A = fixvar    B = filesize  C = maxatom   D = splitsin  E = comiter
F = array     G = locremsv
MTB > noout

```

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```

^Z
```

1

B DATABASE CLIENT/SERVER RATIO

Oct 6 1994 19:11:04 **datcs0.lis** Page 1

```
MTB > #CLIENT/SERVER RATIO FOR DATABASE
MTB > #operation ID 0
MTB > #simple dot plot for operation ID 0
MTB > dotplot c1 c7 c13 c19


              .
              : .   .   .         .                         .
            -+---------+---------+---------+---------+---------+-----s6c1av0
          0.30      0.60      0.90      1.20      1.50      1.80

            .: .     .       .                                   :
           +---------+---------+---------+---------+---------+-------s5c2av0
         0.70      1.05      1.40      1.75      2.10      2.45

             .   :.          .       .                .         .
           +---------+---------+---------+---------+---------+-------s3c4av0
         1.50      2.00      2.50      3.00      3.50      4.00
           .
           :                             .  .      .      .         .
            -+---------+---------+---------+---------+---------+-----s2c5av0
          2.40      3.20      4.00      4.80      5.60      6.40


MTB > #ONE-WAY ANOVA providing
MTB >#confidence intervals
MTB > #F-TESTS
MTB > #Plot residuals(what’s left over after fitting the model) against our fitted va
lues
MTB > # to check for normality
MTB >
MTB > Stack (’s6c1av0’) (’s5c2av0’) (’s3c4av0’) (’s2c5av0’) (’av0’);
SUBC>   Subscripts c48.
MTB > oneway data in c47,levels in c48,[store resids in c49[fits in c50]]

ANALYSIS OF VARIANCE ON av0
SOURCE     DF        SS        MS        F        p
C48         3     57.92     19.31    15.21    0.000
ERROR      28     35.54      1.27
TOTAL      31     93.46
                                   INDIVIDUAL 95% CI’S FOR MEAN
                                   BASED ON POOLED STDEV
 LEVEL      N      MEAN     STDEV  -+---------+---------+---------+-----
     1      8     0.710     0.483  (-----*----)
     2      8     1.379     0.816       (----*-----)
     3      8     2.519     0.989              (-----*----)
     4      8     4.261     1.788                          (----*-----)
                                   -+---------+---------+---------+-----
POOLED STDEV =    1.127           0.0       1.5       3.0       4.5
MTB > plot c49 c50



          -
 resids0 -                                                       *
          -
          -                           *
      1.5+                                                       *
          -   *         2             *                          *
          -
          -                                                      *
          -   *                       *                          *
      0.0+    2          *            *
          -   4          *
          -              4            3
          -                           *
          -
     -1.5+
          -
          -                                                      3
            --+---------+---------+---------+---------+---------+----fits0
            0.70      1.40      2.10      2.80      3.50      4.20
```

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Oct 6 1994 19:13:21 **datcs1.lis** Page 1

```
MTB > #operation ID 1
MTB > dotplot c2 c8 c14 c20


              .         :   ..     .  .                     .
         -------+---------+---------+---------+---------+---------s6c1av1
              2.75      3.00      3.25      3.50      3.75      4.00

           .  .. .     .   .                                 :
         -----+---------+---------+---------+---------+---------+-s5c2av1
            5.60      6.00      6.40      6.80      7.20      7.60

           .            .     . .        .         ..        .
          -+---------+---------+---------+---------+---------+-----s3c4av1
          9.0      10.0      11.0      12.0      13.0      14.0

              .  .         ...           .     .            .
         +---------+---------+---------+---------+---------+-------s2c5av1
       9.0      12.0      15.0      18.0      21.0      24.0

MTB > Stack (’s6c1av1’) (’s5c2av1’) (’s3c4av1’) (’s2c5av1’) (’av1’);
SUBC>   Subscripts c28.
MTB > oneway data in c27,levels in c28,[store resids in c29[fits in c30]]

ANALYSIS OF VARIANCE ON av1
SOURCE     DF        SS        MS        F        p
C28         3    783.24    261.08    40.82    0.000
ERROR      28    179.10      6.40
TOTAL      31    962.34
                                   INDIVIDUAL 95% CI’S FOR MEAN
                                   BASED ON POOLED STDEV
 LEVEL      N      MEAN     STDEV  --------+---------+---------+--------
     1      8     3.114     0.343   (--*---)
     2      8     6.176     0.891         (--*---)
     3      8    11.853     1.716                    (---*--)
     4      8    15.886     4.661                            (---*--)
                                   --------+---------+---------+--------
POOLED STDEV =    2.529                  5.0      10.0      15.0


MTB > plot c29 c30

          -
 resids1 -                                                        *
          -
          -
      5.0+
          -                                                       *
          -
          -                                      *                *
          -   *            2                     2
      0.0+    7            3                     *
          -                3                     3                2
          -                                                       *
          -                                      *
          -
     -5.0+                                                        *
          -                                                       *
          -
           +---------+---------+---------+---------+---------+------fits1
          2.5       5.0       7.5      10.0      12.5      15.0
```

1

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Oct 6 1994 19:15:56 **datcs2.lis** Page 1

```
MTB > #operation ID 2
MTB > dotplot c3 c9 c15 c21


                  ..  ..     . . .                               .
              -----+---------+---------+---------+---------+---------+-s6c1av2
               0.120     0.180     0.240     0.300     0.360     0.420

                     . . .              .            .    :      .
              ---+---------+---------+---------+---------+---------+---s5c2av2
             0.450     0.500     0.550     0.600     0.650     0.700

                .             .      .            .             :. .
             +---------+---------+---------+---------+---------+-------s3c4av2
          1.80      1.92      2.04      2.16      2.28      2.40

                 .          .       .    . .            .        . .
              -------+---------+---------+---------+---------+---------s2c5av2
                  3.00      3.60      4.20      4.80      5.40      6.00

MTB > Stack ('s6c1av2') ('s5c2av2') ('s3c4av2') ('s2c5av2') ('av2');
SUBC>   Subscripts c32.
MTB > oneway data in c31,levels in c32,[store resids in c33[fits in c34]]



ANALYSIS OF VARIANCE ON av2
SOURCE     DF        SS        MS        F        p
C32         3    88.986    29.662    92.85    0.000
ERROR      28     8.945     0.319
TOTAL      31    97.931
                                   INDIVIDUAL 95% CI'S FOR MEAN
                                   BASED ON POOLED STDEV
 LEVEL      N      MEAN     STDEV  --+---------+---------+---------+----
     1      8    0.1814    0.0962  (--*--)
     2      8    0.5747    0.0900     (--*--)
     3      8    2.2276    0.2392               (--*--)
     4      8    4.4132    1.0969                              (-*--)
                                   --+---------+---------+---------+----
POOLED STDEV =   0.5652            0.0       1.5       3.0       4.5
MTB > plot c33 c34

         -
         -                                                    *
      1.2+                                                    *
         -
 resids  -                                                    *
         -
         -   *                           4
      0.0+   7    8                      *                    *
         -                               2                    *
         -                               *                    *
         -
         -                                                    *
     -1.2+
         -
         -                                                    *
         -
         -
           +---------+---------+---------+---------+---------+------fit
         0.00      0.80      1.60      2.40      3.20      4.00

```

1

Oct 6 1994 19:29:31 **datcs3.lis** Page 1

```
MTB > #operation ID 3
MTB > dotplot c4 c10 c16 c22


                .   :         .           .                 .   ..
              -+---------+---------+---------+---------+---------+-----s6c1av3
          0.105     0.120     0.135     0.150     0.165     0.180

                  . .       .                :      .       .       .
              ---+---------+---------+---------+---------+---------+---s5c2av3
             0.450     0.480     0.510     0.540     0.570     0.600

                   . .   .                  .      ..    .         .
              -----+---------+---------+---------+---------+---------+-s3c4av3
                1.90      2.00      2.10      2.20      2.30      2.40

               .              ..   .                .    .  .           .
              -+---------+---------+---------+---------+---------+-----s2c5av3
           2.80      3.50      4.20      4.90      5.60      6.30



MTB > Stack ('s6c1av3') ('s5c2av3') ('s3c4av3') ('s2c5av3') ('av3');
SUBC>   Subscripts c36.
MTB > oneway data in c35,levels in c36,[store resids in c37[fits in c38]]]

ANALYSIS OF VARIANCE ON av3
SOURCE     DF        SS        MS        F        p
C36         3   102.366    34.122    83.10    0.000
ERROR      28    11.497     0.411
TOTAL      31   113.863
                                   INDIVIDUAL 95% CI'S FOR MEAN
                                   BASED ON POOLED STDEV
 LEVEL      N      MEAN     STDEV  ---+---------+---------+---------+---
     1      8    0.1417    0.0334   (--*--)
     2      8    0.5195    0.0549     (--*---)
     3      8    2.1082    0.1778               (--*--)
     4      8    4.6857    1.2675                                (--*--)
                                   ---+---------+---------+---------+---
POOLED STDEV =   0.6408             0.0       1.5       3.0       4.5
MTB > plot c37 c38

 resids3 -
         -
         -                                                  *
      1.5+
         -                                                  *
         -                                                  *
         -                                                  *
         -                      *
      0.0+  8   8               4
         -                      3
         -                                                  *
         -                                                  2
         -
     -1.5+
         -                                                  *
         -
         -
           +---------+---------+---------+---------+---------+------fit3
          0.0       1.0       2.0       3.0       4.0       5.0

```

1

Oct 6 1994 19:18:23 **datcs4.lis** Page 1

```
MTB > #operation ID 4
MTB > dotplot c5 c11 c17 c23


            :.   .:                               .           .
          ---+---------+---------+---------+---------+---------+---s6c1av4
          0.40      0.60      0.80      1.00      1.20      1.40
            .       .
            :  .    :                                              .
          -------+---------+---------+---------+---------+---------s5c2av4
              1.40      2.10      2.80      3.50      4.20      4.90

               :. .:  .                                           .
          ---+---------+---------+---------+---------+---------+---s3c4av4
           2.0       4.0       6.0       8.0      10.0      12.0

         .  ..  .          .          ..                         .
          -----+---------+---------+---------+---------+---------+-s2c5av4
             4.8       6.0       7.2       8.4       9.6      10.8


MTB > Stack ('s6c1av4') ('s5c2av4') ('s3c4av4') ('s2c5av4') ('av4');
SUBC>   Subscripts c40.
MTB > oneway data in c39,levels in c40,[store resids in c41[fits in c42]]

ANALYSIS OF VARIANCE ON av4
SOURCE     DF        SS        MS        F        p
C40         3    149.89     49.96    11.63    0.000
ERROR      28    120.29      4.30
TOTAL      31    270.18
                                   INDIVIDUAL 95% CI'S FOR MEAN
                                   BASED ON POOLED STDEV
 LEVEL      N      MEAN     STDEV  ----+---------+---------+---------+--
     1      8     0.645     0.391   (-----*-----)
     2      8     1.745     1.236       (-----*-----)
     3      8     4.066     3.224               (-----*-----)
     4      8     6.257     2.260                        (-----*-----)
                                   ----+---------+---------+---------+--
POOLED STDEV =    2.073              0.0       2.5       5.0       7.5
MTB > plot c41 c42

         -
         -                                   *
      7.0+
         -
 resids4 -
         -
         -                                                     *
      3.5+
         -                *
         -
         -                                                     2
         -      2
      0.0+      6         3                  *                 *
         -                4                  3
         -                                   2                 2
         -                                   *                 2
         -
           +---------+---------+---------+---------+---------+------fits4
         0.0       1.2       2.4       3.6       4.8       6.0

```

1

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```
MTB > #operation ID 6
MTB > dotplot c6 c12 c18 c24


         .    .   .      .     ..                     .          .
          -------+---------+---------+---------+---------+---------s6c1av6
          0.000175  0.000200  0.000225  0.000250  0.000275  0.000300

              .        :                  .  .      :        .
          -----+---------+---------+---------+---------+---------+-s5c2av6
        0.000315  0.000350  0.000385  0.000420  0.000455  0.000490

           .         .        .             .    ..        .    .
          -----+---------+---------+---------+---------+---------+-s3c4av6
        0.000650  0.000700  0.000750  0.000800  0.000850  0.000900

          .              . .         :               ..          .
         +---------+---------+---------+---------+---------+-------s2c5av6
  0.000800  0.000850  0.000900  0.000950  0.001000  0.001050


MTB > Stack ('s6c1av6') ('s5c2av6') ('s3c4av6') ('s2c5av6') ('av6');
SUBC>   Subscripts c44.
MTB > oneway data in c43,levels in c44,[store resids in c45[fits in c46]]

ANALYSIS OF VARIANCE ON av6
SOURCE     DF        SS        MS        F        p
C44         3 0.0000028 0.0000009   162.73    0.000
ERROR      28 0.0000002 0.0000000
TOTAL      31 0.0000029
                                   INDIVIDUAL 95% CI'S FOR MEAN
                                   BASED ON POOLED STDEV
 LEVEL      N      MEAN     STDEV  ----+---------+---------+---------+--
     1      8  2.10E-04  4.90E-05  (-*--)
     2      8  4.02E-04  5.95E-05          (-*-)
     3      8  7.79E-04  9.27E-05                         (-*-)
     4      8  9.50E-04  9.01E-05                                (-*-)
                                   ----+---------+---------+---------+--
POOLED STDEV = 7.53E-05              0.00025   0.00050   0.00075   0.00100
MTB > plot c45 c46

         -
         -                                          *          *
  0.00010+
         -     *            *                       *          2
 resids6 -     *
         -                  2                       2
         -                  2                       *
  0.00000+     2                                               2
         -     *
         -     2
         -     *            2                       *          2
         -
 -0.00010+                  *                       *
         -
         -                                                     *
         -                                          *
         -
           +---------+---------+---------+---------+---------+------fits6
     0.00015   0.00030   0.00045   0.00060   0.00075   0.00090

MTB > noout


^Z
```

1

C DATABASE LOCAL VS REMOTE DISK

Oct 6 1994 19:44:24 **datlr0.lis** Page 1

```
MTB > #LOCAL VS REMOTE DISK ACCESS FOR DATABASE
MTB > #operation ID 0
MTB > dotplot c1 c7


               :  .:  .   .                                 .
          -----+---------+---------+---------+---------+---------+-lav0
             1.0       2.0       3.0       4.0       5.0       6.0

              ..            .    .       :  .                    .
         +---------+---------+---------+---------+---------+-------rav0
       0.80      1.60      2.40      3.20      4.00      4.80

MTB > Stack ('lav0') ('rav0') ('av0');
SUBC>   Subscripts c14.
MTB > oneway data in c13,levels in c14,[store resids in c15[fits in c16]]

ANALYSIS OF VARIANCE ON av0
SOURCE     DF        SS        MS        F        p
C14         1      3.14      3.14     1.57    0.231
ERROR      14     28.01      2.00
TOTAL      15     31.15
                                   INDIVIDUAL 95% CI'S FOR MEAN
                                   BASED ON POOLED STDEV
 LEVEL      N      MEAN     STDEV  --+---------+---------+---------+----
     1      8     1.938     1.470   (---------*----------)
     2      8     2.823     1.357            (---------*----------)
                                   --+---------+---------+---------+----
POOLED STDEV =    1.414            1.0       2.0       3.0       4.0
MTB > plot c15 c16

      4.0+
         -        *
 resids0 -
         -
         -                                                  *
      2.0+
         -
         -
         -                                                  *
         -                                                  2
      0.0+        2                                         *
         -        2                                         *
         -        3
         -
         -                                                  2
     -2.0+
         -
          +---------+---------+---------+---------+---------+------fits0
        1.80      2.00      2.20      2.40      2.60      2.80
```

1

Oct 6 1994 19:45:44 **datlr1.lis** Page 1

```
MTB > #operation ID 1
MTB > dotplot c2 c8




            .     . ..    .                          :        .
         +---------+---------+---------+---------+---------+-------lav1
       8.00      8.80      9.60     10.40     11.20     12.00

              .              . . .          .              . ..
         +---------+---------+---------+---------+---------+-------rav1
       12.0      13.0      14.0      15.0      16.0      17.0

MTB > Stack ('lav1') ('rav1') ('av1');
SUBC>   Subscripts c18.
MTB > oneway data in c17,levels in c18,[store resids in c19[fits in c20]]

ANALYSIS OF VARIANCE ON av1
SOURCE     DF        SS        MS        F        p
C18         1    112.43    112.43    40.27    0.000
ERROR      14     39.09      2.79
TOTAL      15    151.52
                                   INDIVIDUAL 95% CI'S FOR MEAN
                                   BASED ON POOLED STDEV
 LEVEL      N      MEAN     STDEV  ------+---------+---------+---------+
     1      8     9.859     1.560  (----*-----)
     2      8    15.161     1.775                       (----*----)
                                   ------+---------+---------+---------+
POOLED STDEV =    1.671               10.0      12.5      15.0      17.5
MTB > plot c19 c20

         -
         -    *
      2.0+                                                      2
         -    2                                                 *
 resids1 -
         -
         -                                                      *
      0.0+
         -    *
         -    *                                                 *
         -    2                                                 2
         -    *
     -2.0+
         -
         -                                                      *
         -
         -
          ----+---------+---------+---------+---------+---------+--fits1
             10.0      11.0      12.0      13.0      14.0      15.0
```

1

Oct 6 1994 19:47:03 **datlr2.lis** Page 1

```
MTB > #operation ID2
MTB > dotplot c3 c9


             .    .   .     .         .     .         .          .
           -------+---------+---------+---------+---------+---------lav2
               1.75      2.10      2.45      2.80      3.15      3.50

              .                .         : .         .   .   .
           -+---------+---------+---------+---------+---------+-----rav2
         2.10      2.40      2.70      3.00      3.30      3.60



MTB > Stack ('lav2') ('rav2') ('av2');
SUBC>   Subscripts c22.
MTB > oneway data in c21,levels in c22,[store resids in c23[fits in c24]]

ANALYSIS OF VARIANCE ON av2
SOURCE     DF        SS        MS        F        p
C22         1     1.784     1.784     5.83    0.030
ERROR      14     4.283     0.306
TOTAL      15     6.067
                                   INDIVIDUAL 95% CI'S FOR MEAN
                                   BASED ON POOLED STDEV
 LEVEL      N      MEAN     STDEV  --+---------+---------+---------+----
     1      8    2.3501    0.6362   (-------*-------)
     2      8    3.0180    0.4550               (-------*--------)
                                   --+---------+---------+---------+----
POOLED STDEV =   0.5531            2.00      2.50      3.00      3.50
MTB > plot c23 c24

 resids2 -
         -        *
         -
     0.70+        *
         -                                            *
         -                                            *
         -        *                                   *
         -        *
     0.00+                                            3
         -
         -        *
         -        *                                   *
         -        *
    -0.70+
         -        *                                   *
         -
         -
           +---------+---------+---------+---------+---------+------fits
         2.25      2.40      2.55      2.70      2.85      3.00

```

1

Oct 6 1994 19:48:19 **datlr3.lis** Page 1

```
MTB > #operation ID 3
MTB > dotplot c4 c10


             .    .   .   . .       :                       .
           -----+---------+---------+---------+---------+---------+-lav3
             1.60      2.00      2.40      2.80      3.20      3.60

            .               .    .  .   .         .  .           .
           -+---------+---------+---------+---------+---------+-----rav3
         2.10      2.40      2.70      3.00      3.30      3.60

MTB > Stack ('lav3') ('rav3') ('av3');
SUBC>   Subscripts c26.
MTB > oneway data in c25,levels in c26[store resids in c27[fits in c28]]



ANALYSIS OF VARIANCE ON av3
SOURCE     DF        SS        MS        F        p
C26         1     1.902     1.902     6.58    0.022
ERROR      14     4.045     0.289
TOTAL      15     5.947
                                   INDIVIDUAL 95% CI'S FOR MEAN
                                   BASED ON POOLED STDEV
 LEVEL      N      MEAN     STDEV  ----+---------+---------+---------+--
     1      8    2.2272    0.5875  (--------*-------)
     2      8    2.9167    0.4824               (-------*-------)
                                   ----+---------+---------+---------+--
POOLED STDEV =   0.5375              2.00      2.50      3.00      3.50
MTB > plot c27 c28

         -     *
 resids3 -
         -
         -
     0.70+                                            *
         -
         -                                            *
         -     2                                      *
         -
     0.00+     *                                      *
         -     *                                      2
         -     *                                      *
         -     *
         -
    -0.70+     *
         -                                            *
         -
           ------+---------+---------+---------+---------+---------+fits3
               2.25      2.40      2.55      2.70      2.85      3.00

```

1

Oct 6 1994 19:49:42 **datlr4.lis** Page 1

```
MTB > #operation ID 4
MTB > dotplot c5 c11


               . ::.                .                        .
         +---------+---------+---------+---------+---------+-------lav4
      1.80      2.40      3.00      3.60      4.20      4.80

             . .   .           :   .       .                   .
          ---+---------+---------+---------+---------+---------+---rav4
          3.50      4.20      4.90      5.60      6.30      7.00

MTB > Stack ('lav4') ('rav4') ('av4');
SUBC>   Subscripts c30.
MTB > oneway data in c29,levels in c30,[store resids in c31[fits in c32]]



ANALYSIS OF VARIANCE ON av4
SOURCE     DF        SS        MS        F        p
C30         1     16.26     16.26    14.52    0.002
ERROR      14     15.67      1.12
TOTAL      15     31.92
                                     INDIVIDUAL 95% CI'S FOR MEAN
                                     BASED ON POOLED STDEV
 LEVEL      N      MEAN     STDEV  -+---------+---------+---------+-----
     1      8     2.766     0.955   (-------*-------)
     2      8     4.782     1.152                      (-------*-------)
                                   -+---------+---------+---------+-----
POOLED STDEV =    1.058           2.0       3.0       4.0       5.0
```

Oct 6 1994 19:50:47 **datlr6.lis** Page 1

```
MTB > #operation ID 6
MTB > dotplot c6 c12


            ..      : :         .                                .
         +---------+---------+---------+---------+---------+-------lav6
   0.00048   0.00060   0.00072   0.00084   0.00096   0.00108

             ..      .  .       .       .        .          .
         +---------+---------+---------+---------+---------+-------rav6
   0.00045   0.00060   0.00075   0.00090   0.00105   0.00120

MTB > Stack ('lav6') ('rav6') ('av6');
SUBC>   Subscripts c34.
MTB > oneway data in c33,levels in c34,[store resids in c35[fits in c36]]

ANALYSIS OF VARIANCE ON av6
SOURCE     DF        SS        MS        F        p
C34         1 0.0000000 0.0000000     0.94    0.350
ERROR      14 0.0000007 0.0000001
TOTAL      15 0.0000008
                                     INDIVIDUAL 95% CI'S FOR MEAN
                                     BASED ON POOLED STDEV
 LEVEL      N      MEAN     STDEV  -------+---------+---------+---------
     1      8  6.79E-04  2.01E-04   (----------*-----------)
     2      8  7.89E-04  2.52E-04          (-----------*----------)
                                   -------+---------+---------+---------
POOLED STDEV = 2.28E-04                 0.00060   0.00075   0.00090
MTB > plot c35 c36



  0.00050+
         -         *
 resids6 -                                            *
         -
         -
  0.00025+                                            *
         -
         -                                            *
         -
         -         *
  0.00000+                                            *
         -         4
         -                                            *
         -         2                                  *
         -
 -0.00025+                                            2
         -
           ------+---------+---------+---------+---------+---------+fits6
          0.000675  0.000700  0.000725  0.000750  0.000775  0.000800

MTB > noout


^Z
```

1

1

D FILTER FFD

Oct 6 1994 19:56:47 **ffd0.lis** Page 1

```
MTB > #fractional factorial experiment for FILTER
MTB > ffdesign 7 16;
SUBC> xmatrix c1-c7.

Fractional Factorial Design

Factors:   7    Design:     7, 16     Resolution: IV
Runs:     16    Replicates:     1     Fraction: 1/8
Blocks: none    Center points:  0

Design Generators:  E = ABC  F = BCD  G = ACD

Alias Structure (up to order 3)

I

A + BCE + BFG + CDG + DEF
B + ACE + AFG + CDF + DEG
C + ABE + ADG + BDF + EFG
D + ACG + AEF + BCF + BEG
E + ABC + ADF + BDG + CFG
F + ABG + ADE + BCD + CEG
G + ABF + ACD + BDE + CEF
AB + CE + FG
AC + BE + DG
AD + CG + EF
AE + BC + DF
AF + BG + DE
AG + BF + CD
BD + CF + EG
ABD + ACF + AEG + BCG + BEF + CDE + DFG

NOTE *** Data window was used to change the worksheet
MTB > Save  'A:\FILTER\FILFFD.MTW';
SUBC>   Replace.
Saving worksheet in file: A:\FILTER\FILFFD.MTW
MTB > print c1-c7


 ROW  fixvar  filesize  maxatom  splitsin  comiter  array  locremsv

   1      -1        -1       -1        -1       -1     -1        -1
   2       1        -1       -1        -1        1     -1         1
   3      -1         1       -1        -1        1      1        -1
   4       1         1       -1        -1       -1      1         1
   5      -1        -1        1        -1        1      1         1
   6       1        -1        1        -1       -1      1        -1
   7      -1         1        1        -1       -1     -1         1
   8       1         1        1        -1        1     -1        -1
   9      -1        -1       -1         1       -1      1         1
  10       1        -1       -1         1        1      1        -1
  11      -1         1       -1         1        1     -1         1
  12       1         1       -1         1       -1     -1        -1
  13      -1        -1        1         1        1     -1        -1
  14       1        -1        1         1       -1     -1         1
  15      -1         1        1         1       -1      1        -1
  16       1         1        1         1        1      1         1


MTB > operation ID 0
MTB > ffactorial avtime0=(fixvar-locremsv)2;
SUBC> eplot;
SUBC> effects c32.

Alias Information for Terms in the Model.
Totally confounded terms were removed from the analysis

fixvar*filesize + maxatom*comiter + array*locremsv
fixvar*maxatom + filesize*comiter + splitsin*locremsv
fixvar*splitsin + maxatom*locremsv + comiter*array
fixvar*comiter + filesize*maxatom + splitsin*array
```

Oct 6 1994 19:56:47 **ffd0.lis** Page 2

```
fixvar*array + filesize*locremsv + splitsin*comiter
fixvar*locremsv + filesize*array + maxatom*splitsin
filesize*splitsin + maxatom*array + comiter*locremsv

Estimated Effects and Coefficients for avtime0

Term                 Effect      Coef  Std Coef t-value      P
Constant                       1.4024   0.03739   37.51  0.017
fixvar              -0.0575   -0.0288   0.03739   -0.77  0.583
filesize            -0.2534   -0.1267   0.03739   -3.39  0.183
maxatom             -0.1827   -0.0913   0.03739   -2.44  0.247
splitsin            -0.1459   -0.0729   0.03739   -1.95  0.302
comiter             -0.0240   -0.0120   0.03739   -0.32  0.802
array               -0.1345   -0.0672   0.03739   -1.80  0.323
locremsv             0.1004    0.0502   0.03739    1.34  0.407
fixvar*filesize      0.3560    0.1780   0.03739    4.76  0.132
fixvar*maxatom       0.2901    0.1451   0.03739    3.88  0.161
fixvar*splitsin      0.3193    0.1596   0.03739    4.27  0.146
fixvar*comiter       0.4169    0.2085   0.03739    5.58  0.113
fixvar*array         0.2904    0.1452   0.03739    3.88  0.160
fixvar*locremsv      0.4241    0.2120   0.03739    5.67  0.111
filesize*splitsin    0.4593    0.2296   0.03739    6.14  0.103

Analysis of Variance for avtime0

Source               DF      Seq SS     Adj SS     Adj MS      F      P
Main Effects          7     0.60370    0.60370    0.08624   3.86  0.374
2-Way Interactions    7     3.84715    3.84715    0.54959  24.57  0.154
Residual Error        1     0.02237    0.02237    0.02237
Total                15     4.47322




 Nscores -
        -                                             *  BD
        -
     1.2+                                           *    AG
        -                                          *    AE
        -                                      *    AB
        -                                    *    AD
        -                                  *    AF
     0.0+                       *          *    G,AC
        -               *    E
        -             *    A
        -         *    F
        -        *    D
    -1.2+      *    C
        -
        - *    B
        -
          ------+---------+---------+---------+---------+Effects
              -0.16      0.00      0.16      0.32      0.48

A = fixvar    B = filesize  C = maxatom   D = splitsin  E = comiter
F = array     G = locremsv
```

1

Oct 6 1994 19:59:32 **ffd1a.lis** Page 1

```
MTB > #operation ID 1
MTB > ffactorial avtime1=(fixvar-locremsv)2;
SUBC> eplot;
SUBC> effects c32.

Alias Information for Terms in the Model.
Totally confounded terms were removed from the analysis

fixvar*filesize + maxatom*comiter + array*locremsv
fixvar*maxatom + filesize*comiter + splitsin*locremsv
fixvar*splitsin + maxatom*locremsv + comiter*array
fixvar*comiter + filesize*maxatom + splitsin*array
fixvar*array + filesize*locremsv + splitsin*comiter
fixvar*locremsv + filesize*array + maxatom*splitsin
filesize*splitsin + maxatom*array + comiter*locremsv

Estimated Effects and Coefficients for avtime1

Term                 Effect      Coef  Std Coef t-value      P
Constant                       4.7947   0.09616   49.86  0.013
fixvar              -0.1226   -0.0613   0.09616   -0.64  0.639
filesize             0.4092    0.2046   0.09616    2.13  0.280
maxatom             -0.0407   -0.0203   0.09616   -0.21  0.867
splitsin            -0.8439   -0.4219   0.09616   -4.39  0.143
comiter             -0.3717   -0.1859   0.09616   -1.93  0.304
array               -0.1296   -0.0648   0.09616   -0.67  0.623
locremsv            -0.3509   -0.1754   0.09616   -1.82  0.319
fixvar*filesize     -0.0369   -0.0185   0.09616   -0.19  0.879
fixvar*maxatom       0.2305    0.1153   0.09616    1.20  0.443
fixvar*splitsin      0.1371    0.0686   0.09616    0.71  0.606
fixvar*comiter       0.1640    0.0820   0.09616    0.85  0.551
fixvar*array        -0.1649   -0.0824   0.09616   -0.86  0.549
fixvar*locremsv      0.1489    0.0745   0.09616    0.77  0.581
filesize*splitsin    0.1214    0.0607   0.09616    0.63  0.642



Analysis of Variance for avtime1

Source               DF      Seq SS     Adj SS     Adj MS      F      P
Main Effects          7      4.6973     4.6973    0.67104   4.54  0.347
2-Way Interactions    7      0.6572     0.6572    0.09388   0.63  0.750
Residual Error        1      0.1480     0.1480    0.14795
Total                15      5.5024


 Nscores -
        -                                        * B
        -
     1.2+                                  *    AC
        -                               *    AE
        -                               *    AG
        -                               *    AD
        -                              *    BD
     0.0+                       2    C,AB
        -                    *    A
        -                    *    F
        -                   *    AF
        -            *    G
    -1.2+            *    E
        -
        -    *    D
        -
          --+---------+---------+---------+---------+----Effects
          -0.90     -0.60     -0.30      0.00      0.30

A = fixvar    B = filesize  C = maxatom   D = splitsin  E = comiter
F = array     G = locremsv
```

1

```
MTB > #compare standard deviation for operation ID 1
MTB > let c33=20*logten(c10/c11)

MTB > ffactorial c33=(fixvar-locremsv)2;
SUBC> eplot;
SUBC> effects c32;
SUBC> .



Alias Information for Terms in the Model.
Totally confounded terms were removed from the analysis

fixvar*filesize + maxatom*comiter + array*locremsv
fixvar*maxatom + filesize*comiter + splitsin*locremsv
fixvar*splitsin + maxatom*locremsv + comiter*array
fixvar*comiter + filesize*maxatom + splitsin*array
fixvar*array + filesize*locremsv + splitsin*comiter
fixvar*locremsv + filesize*array + maxatom*splitsin
filesize*splitsin + maxatom*array + comiter*locremsv

Estimated Effects and Coefficients for C33

Term                 Effect      Coef  Std Coef t-value      P
Constant                       5.9299    0.4080   14.53  0.044
fixvar              -0.2554   -0.1277    0.4080   -0.31  0.807
filesize            -0.2176   -0.1088    0.4080   -0.27  0.834
maxatom             -0.1260   -0.0630    0.4080   -0.15  0.903
splitsin             1.0942    0.5471    0.4080    1.34  0.408
comiter              0.8741    0.4370    0.4080    1.07  0.478
array                0.5424    0.2712    0.4080    0.66  0.627
locremsv             0.9802    0.4901    0.4080    1.20  0.442
fixvar*filesize     -0.6639   -0.3320    0.4080   -0.81  0.565
fixvar*maxatom       0.0105    0.0052    0.4080    0.01  0.992
fixvar*splitsin     -0.4258   -0.2129    0.4080   -0.52  0.694
fixvar*comiter      -0.6061   -0.3031    0.4080   -0.74  0.593
fixvar*array         0.1240    0.0620    0.4080    0.15  0.904
fixvar*locremsv     -0.2853   -0.1426    0.4080   -0.35  0.786
filesize*splitsin   -0.6704   -0.3352    0.4080   -0.82  0.562

Analysis of Variance for C33

Source               DF      Seq SS      Adj SS      Adj MS       F       P
Main Effects          7      13.379      13.379      1.9112    0.72   0.724
2-Way Interactions    7       6.143       6.143      0.8776    0.33   0.875
Residual Error        1       2.663       2.663      2.6635
Total                15      22.185


 Nscores -
         -                                             *  D
         -
      1.2+                                           *    G
         -                                         *    E
         -                                  *    F
         -                       *    AF
         -                    *    AC
      0.0+               * *    B,C
         -              *    A
         -             *    AG
         -         *    AD
         -     *    AE
     -1.2+  *    AB
         -
         -  *    BD
         -
           --------+---------+---------+---------+--------Effects
               -0.40      0.00      0.40      0.80


```



```
A = fixvar    B = filesize  C = maxatom   D = splitsin  E = comiter
F = array     G = locremsv
```

1


```
MTB > operation ID 2
MTB > ffactorial avtime2=(fixvar-locremsv)2;
SUBC> eplot;
SUBC> effects c32.

Alias Information for Terms in the Model.
Totally confounded terms were removed from the analysis

fixvar*filesize + maxatom*comiter + array*locremsv
fixvar*maxatom + filesize*comiter + splitsin*locremsv
fixvar*splitsin + maxatom*locremsv + comiter*array
fixvar*comiter + filesize*maxatom + splitsin*array
fixvar*array + filesize*locremsv + splitsin*comiter
fixvar*locremsv + filesize*array + maxatom*splitsin
filesize*splitsin + maxatom*array + comiter*locremsv

Estimated Effects and Coefficients for avtime2

Term                 Effect      Coef  Std Coef t-value      P
Constant                      1.19222  0.007313  163.03  0.004
fixvar              0.18892   0.09446  0.007313   12.92  0.049
filesize           -0.14339  -0.07170  0.007313   -9.80  0.065
maxatom            -0.10469  -0.05235  0.007313   -7.16  0.088
splitsin            0.09170   0.04585  0.007313    6.27  0.101
comiter             0.01890   0.00945  0.007313    1.29  0.419
array               0.18489   0.09244  0.007313   12.64  0.050
locremsv            0.12143   0.06072  0.007313    8.30  0.076
fixvar*filesize    -0.05239  -0.02620  0.007313   -3.58  0.173
fixvar*maxatom      0.11462   0.05731  0.007313    7.84  0.081
fixvar*splitsin     0.18288   0.09144  0.007313   12.50  0.051
fixvar*comiter      0.03630   0.01815  0.007313    2.48  0.244
fixvar*array        0.01925   0.00962  0.007313    1.32  0.414
fixvar*locremsv    -0.13415  -0.06707  0.007313   -9.17  0.069
filesize*splitsin  -0.05005  -0.02503  0.007313   -3.42  0.181

Analysis of Variance for avtime2

Source               DF      Seq SS      Adj SS      Adj MS       F       P
Main Effects          7    0.499624    0.499624   0.0713748   83.41   0.084
2-Way Interactions    7    0.286071    0.286071   0.0408672   47.76   0.111
Residual Error        1    0.000856    0.000856   0.0008557
Total                15    0.786550




 Nscores -
         -                                            *   A
         -
      1.2+                                           *    F
         -                                           *    AD
         -                                   *    G
         -                                  *    AC
         -                               *    D
      0.0+                      *  *     AF,AE
         -                      *    E
         -              *    BD
         -             *    AB
         -       *    C
     -1.2+   *    AG
         -
         -  *    B
         -
           +---------+---------+---------+---------+------Effects
     -0.160    -0.080     0.000     0.080     0.160

A = fixvar    B = filesize  C = maxatom   D = splitsin  E = comiter
F = array     G = locremsv
```

1

```
MTB > #compare standard deviation for operation ID 2
MTB > let c33=20*logten(c12/c13)
MTB > ffactorial c33=(fixvar-locrem)2;
* ERROR * Illegal variable name or undefined name or
          improper use of quote


MTB > ffactorial c33=(fixvar-locremsv)2;
SUBC> eplot;
SUBC> effects c32.

Alias Information for Terms in the Model.
Totally confounded terms were removed from the analysis

fixvar*filesize + maxatom*comiter + array*locremsv
fixvar*maxatom + filesize*comiter + splitsin*locremsv
fixvar*splitsin + maxatom*locremsv + comiter*array
fixvar*comiter + filesize*maxatom + splitsin*array
fixvar*array + filesize*locremsv + splitsin*comiter
fixvar*locremsv + filesize*array + maxatom*splitsin
filesize*splitsin + maxatom*array + comiter*locremsv



Estimated Effects and Coefficients for C33

Term                  Effect      Coef  Std Coef t-value      P
Constant                         4.219    0.6497    6.49  0.097
fixvar                -1.323    -0.662    0.6497   -1.02  0.494
filesize               1.818     0.909    0.6497    1.40  0.395
maxatom                0.214     0.107    0.6497    0.16  0.896
splitsin              -7.208    -3.604    0.6497   -5.55  0.114
comiter               -1.414    -0.707    0.6497   -1.09  0.473
array                 -3.569    -1.784    0.6497   -2.75  0.222
locremsv               5.778     2.889    0.6497    4.45  0.141
fixvar*filesize       -0.631    -0.315    0.6497   -0.49  0.712
fixvar*maxatom        -0.798    -0.399    0.6497   -0.61  0.649
fixvar*splitsin        0.346     0.173    0.6497    0.27  0.834
fixvar*comiter         1.666     0.833    0.6497    1.28  0.422
fixvar*array           0.569     0.285    0.6497    0.44  0.737
fixvar*locremsv       -0.071    -0.036    0.6497   -0.05  0.965
filesize*splitsin     -1.553    -0.777    0.6497   -1.20  0.444

Analysis of Variance for C33

Source                DF      Seq SS      Adj SS      Adj MS      F      P
Main Effects           7     420.682     420.682      60.097   8.90  0.253
2-Way Interactions     7      26.689      26.689       3.813   0.56  0.775
Residual Error         1       6.753       6.753       6.753
Total                 15     454.124


 Nscores -
         -                                          *  G
         -
      1.2+                              *    B
         -                              *    AE
         -                          *    AF
         -                         *    AD
         -                         *    C
      0.0+                     * *    AB,AG
         -                    *    AC
         -                   *    A
         -                  *    E
         -                  *    BD
     -1.2+           *    F
         -
         -  *    D
         -
           ------+---------+---------+---------+---------+Effects
               -6.0      -3.0       0.0       3.0       6.0
```



```
A = fixvar    B = filesize  C = maxatom   D = splitsin  E = comiter
F = array     G = locremsv
```



```
MTB > #operation ID 3
MTB > ffactorial avtime3=(fixvar-locremsv)2;
SUBC> eplot;
SUBC> effects c32.

Alias Information for Terms in the Model.
Totally confounded terms were removed from the analysis

fixvar*filesize + maxatom*comiter + array*locremsv


fixvar*maxatom + filesize*comiter + splitsin*locremsv
fixvar*splitsin + maxatom*locremsv + comiter*array
fixvar*comiter + filesize*maxatom + splitsin*array
fixvar*array + filesize*locremsv + splitsin*comiter
fixvar*locremsv + filesize*array + maxatom*splitsin
filesize*splitsin + maxatom*array + comiter*locremsv

Estimated Effects and Coefficients for avtime3

Term                  Effect      Coef  Std Coef t-value      P
Constant                        1.1113   0.03450   32.21  0.020
fixvar               -0.1315   -0.0658   0.03450   -1.91  0.308
filesize              0.0939    0.0469   0.03450    1.36  0.404
maxatom               0.2358    0.1179   0.03450    3.42  0.181
splitsin             -0.0087   -0.0044   0.03450   -0.13  0.920
comiter              -0.0913   -0.0456   0.03450   -1.32  0.412
array                 0.1117    0.0558   0.03450    1.62  0.352
locremsv             -0.2512   -0.1256   0.03450   -3.64  0.171
fixvar*filesize      -0.1102   -0.0551   0.03450   -1.60  0.356
fixvar*maxatom       -0.2764   -0.1382   0.03450   -4.01  0.156
fixvar*splitsin      -0.1143   -0.0572   0.03450   -1.66  0.346
fixvar*comiter       -0.0470   -0.0235   0.03450   -0.68  0.619
fixvar*array         -0.0387   -0.0193   0.03450   -0.56  0.675
fixvar*locremsv       0.2020    0.1010   0.03450    2.93  0.210
filesize*splitsin     0.1581    0.0790   0.03450    2.29  0.262

Analysis of Variance for avtime3

Source                DF      Seq SS      Adj SS      Adj MS      F      P
Main Effects           7     0.66273     0.66273     0.09468   4.97  0.333
2-Way Interactions     7     0.68456     0.68456     0.09779   5.14  0.328
Residual Error         1     0.01904     0.01904     0.01904
Total                 15     1.36633


 Nscores -
         -                                          * C
         -
      1.2+                                      *    AG
         -                                  *    BD
         -                              *    F
         -                             *    B
         -                    *    D
      0.0+                 **    AE,AF
         -             *    E
         -            *    AB
         -           *    AD
         -          *    A
     -1.2+      *    G
         -
         -    *    AC
         -
           ------+---------+---------+---------+---------+Effects
              -0.24     -0.12      0.00      0.12      0.24

A = fixvar    B = filesize  C = maxatom   D = splitsin  E = comiter
F = array     G = locremsv
```

Oct 6 1994 20:13:15 **ffd3s.lis** Page 1

```
MTB > #compare standard deviation for operation ID 3
MTB > let c33=20*logten(c14/c15)
MTB > ffactorial c33=(fixvar-locremsv)2;
SUBC> eplot;
SUBC> effects c32.

Alias Information for Terms in the Model.
Totally confounded terms were removed from the analysis

fixvar*filesize + maxatom*comiter + array*locremsv
fixvar*maxatom + filesize*comiter + splitsin*locremsv
fixvar*splitsin + maxatom*locremsv + comiter*array
fixvar*comiter + filesize*maxatom + splitsin*array
fixvar*array + filesize*locremsv + splitsin*comiter
fixvar*locremsv + filesize*array + maxatom*splitsin
filesize*splitsin + maxatom*array + comiter*locremsv

Estimated Effects and Coefficients for C33

Term                 Effect      Coef  Std Coef t-value      P
Constant                        3.205    0.7797    4.11  0.152
fixvar               -1.658    -0.829    0.7797   -1.06  0.481
filesize              2.206     1.103    0.7797    1.41  0.392
maxatom               1.055     0.527    0.7797    0.68  0.621
splitsin             -9.852    -4.926    0.7797   -6.32  0.100
comiter              -1.351    -0.676    0.7797   -0.87  0.545
array                -4.198    -2.099    0.7797   -2.69  0.226
locremsv              4.968     2.484    0.7797    3.19  0.194
fixvar*filesize      -1.677    -0.839    0.7797   -1.08  0.477
fixvar*maxatom       -2.095    -1.048    0.7797   -1.34  0.407
fixvar*splitsin       0.149     0.074    0.7797    0.10  0.939
fixvar*comiter        1.858     0.929    0.7797    1.19  0.445
fixvar*array          1.384     0.692    0.7797    0.89  0.538
fixvar*locremsv       0.964     0.482    0.7797    0.62  0.648
filesize*splitsin    -0.023    -0.012    0.7797   -0.01  0.991

Analysis of Variance for C33

Source               DF      Seq SS     Adj SS     Adj MS      F      P
Main Effects          7     599.691    599.691     85.670   8.81  0.254
2-Way Interactions    7      54.093     54.093      7.728   0.79  0.701
Residual Error        1       9.727      9.727      9.727
Total                15     663.511




 Nscores -
         -                                             *   G
         -
      1.2+                                     *    B
         -                                    *    AE
         -                                   *    AF
         -                                  *    C
         -                                  *    AG
      0.0+                               2    AD,BD
         -                           *    E
         -                          *    A
         -                          *    AB
         -                         *    AC
     -1.2+                   *    F
         -
         -   *    D
         -
           +---------+---------+---------+---------+------Effects
       -10.5      -7.0      -3.5       0.0       3.5

A = fixvar    B = filesize  C = maxatom   D = splitsin  E = comiter
F = array     G = locremsv
```

1

~~Oct 6 1994 20:17:03~~ **ffd4a.lis** ~~Page 1~~

```
MTB > #operation ID 4
MTB > ffactorial avtime4=(fixvar-locremsv)2;
SUBC> eplot;
SUBC> effects c32.

Alias Information for Terms in the Model.
Totally confounded terms were removed from the analysis

fixvar*filesize + maxatom*comiter + array*locremsv
fixvar*maxatom + filesize*comiter + splitsin*locremsv
fixvar*splitsin + maxatom*locremsv + comiter*array
fixvar*comiter + filesize*maxatom + splitsin*array
fixvar*array + filesize*locremsv + splitsin*comiter
fixvar*locremsv + filesize*array + maxatom*splitsin
filesize*splitsin + maxatom*array + comiter*locremsv

Estimated Effects and Coefficients for avtime4

Term                 Effect      Coef  Std Coef t-value      P
Constant                       3.8602    0.1039   37.17  0.017
fixvar              -1.0230   -0.5115    0.1039   -4.92  0.128
filesize             0.9455    0.4728    0.1039    4.55  0.138
maxatom              1.6893    0.8446    0.1039    8.13  0.078
splitsin             1.3614    0.6807    0.1039    6.55  0.096
comiter              0.1942    0.0971    0.1039    0.93  0.521
array                3.6815    1.8408    0.1039   17.72  0.036
locremsv            -0.3557   -0.1778    0.1039   -1.71  0.337
fixvar*filesize     -0.4353   -0.2176    0.1039   -2.10  0.283
fixvar*maxatom      -0.2004   -0.1002    0.1039   -0.96  0.511
fixvar*splitsin      0.0911    0.0456    0.1039    0.44  0.737
fixvar*comiter       1.0556    0.5278    0.1039    5.08  0.124
fixvar*array        -0.6520   -0.3260    0.1039   -3.14  0.196
fixvar*locremsv      0.9697    0.4849    0.1039    4.67  0.134
filesize*splitsin    1.9837    0.9919    0.1039    9.55  0.066



Analysis of Variance for avtime4

Source               DF      Seq SS     Adj SS     Adj MS      F      P
Main Effects          7      81.461    81.4606    11.6372  67.42  0.094
2-Way Interactions    7      26.611    26.6114     3.8016  22.02  0.163
Residual Error        1       0.173     0.1726     0.1726
Total                15     108.245


 Nscores -
         -                                            *    F
         -
      1.2+                              *    BD
         -                           *    C
         -                        *    D
         -                      *    AE
         -                     *    AG
      0.0+               *     *    E,B
         -              *    AD
         -           *    AC
         -          *    G
         -         *    AB
     -1.2+        *    AF
         -
         -    *    A
         -
           --+---------+---------+---------+---------+----Effects
          -1.2       0.0       1.2       2.4       3.6

A = fixvar    B = filesize  C = maxatom   D = splitsin  E = comiter
F = array     G = locremsv
```

1

Oct 6 1994 20:18:32 **ffd4s.lis** Page 1

```
MTB > #compare standard deviation for operation ID 4
MTB > let c33 =20*logten(c16/c17)
MTB > ffactorial c33=(fixvar-locremsv)2;
SUBC> eplot;
SUBC> effects c32.

Alias Information for Terms in the Model.
Totally confounded terms were removed from the analysis

fixvar*filesize + maxatom*comiter + array*locremsv
fixvar*maxatom + filesize*comiter + splitsin*locremsv
fixvar*splitsin + maxatom*locremsv + comiter*array
fixvar*comiter + filesize*maxatom + splitsin*array
fixvar*array + filesize*locremsv + splitsin*comiter
fixvar*locremsv + filesize*array + maxatom*splitsin
filesize*splitsin + maxatom*array + comiter*locremsv



Estimated Effects and Coefficients for C33

Term                 Effect      Coef  Std Coef t-value      P
Constant                        7.803    0.3374   23.13  0.028
fixvar                2.352     1.176    0.3374    3.49  0.178
filesize              1.520     0.760    0.3374    2.25  0.266
maxatom              -2.876    -1.438    0.3374   -4.26  0.147
splitsin             -6.970    -3.485    0.3374  -10.33  0.061
comiter              -1.105    -0.553    0.3374   -1.64  0.349
array                -7.909    -3.954    0.3374  -11.72  0.054
locremsv             -0.821    -0.410    0.3374   -1.22  0.438
fixvar*filesize       2.381     1.191    0.3374    3.53  0.176
fixvar*maxatom       -2.705    -1.353    0.3374   -4.01  0.156
fixvar*splitsin       2.729     1.364    0.3374    4.04  0.154
fixvar*comiter        1.037     0.518    0.3374    1.54  0.367
fixvar*array         -2.282    -1.141    0.3374   -3.38  0.183
fixvar*locremsv       0.210     0.105    0.3374    0.31  0.808
filesize*splitsin    -1.677    -0.838    0.3374   -2.48  0.244

Analysis of Variance for C33

Source               DF      Seq SS     Adj SS     Adj MS      F      P
Main Effects          7     516.564    516.564     73.795  40.51  0.120
2-Way Interactions    7     118.288    118.288     16.898   9.28  0.248
Residual Error        1       1.822      1.822      1.822
Total                15     636.674


 Nscores -
         -                                            *  AD
         -
      1.2+                                           *   AB
         -                                          *    A
         -                                       *    B
         -                                     *    AE
         -                                  *    AG
      0.0+                             **     E,G
         -                          *    BD
         -                        *    AF
         -                      *    AC
         -                     *    C
     -1.2+       *    D
         -
         -   *    F
         -
           ----+---------+---------+---------+---------+--Effects
             -7.5      -5.0      -2.5       0.0       2.5

A = fixvar    B = filesize  C = maxatom   D = splitsin  E = comiter
F = array     G = locremsv
```

1

Oct 6 1994 20:19:46 **ffd6a.lis** Page 1

```
MTB >#operation ID 6
MTB > ffactorial avtime6=(fixvar-locremsv)2;
SUBC> eplot;
SUBC> effects c32.

Alias Information for Terms in the Model.
Totally confounded terms were removed from the analysis

fixvar*filesize + maxatom*comiter + array*locremsv


fixvar*maxatom + filesize*comiter + splitsin*locremsv
fixvar*splitsin + maxatom*locremsv + comiter*array
fixvar*comiter + filesize*maxatom + splitsin*array
fixvar*array + filesize*locremsv + splitsin*comiter
fixvar*locremsv + filesize*array + maxatom*splitsin
filesize*splitsin + maxatom*array + comiter*locremsv

Estimated Effects and Coefficients for avtime6

Term                 Effect      Coef  Std Coef t-value      P
Constant                     0.000671  0.000027   24.55  0.026
fixvar            -0.000001 -0.000000  0.000027   -0.02  0.990
filesize          -0.000042 -0.000021  0.000027   -0.76  0.585
maxatom            0.000066  0.000033  0.000027    1.21  0.441
splitsin           0.000053  0.000026  0.000027    0.97  0.510
comiter           -0.000214 -0.000107  0.000027   -3.92  0.159
array              0.000045  0.000022  0.000027    0.82  0.562
locremsv           0.000118  0.000059  0.000027    2.16  0.276
fixvar*filesize    0.000009  0.000004  0.000027    0.16  0.897
fixvar*maxatom     0.000075  0.000038  0.000027    1.38  0.399
fixvar*splitsin   -0.000029 -0.000014  0.000027   -0.52  0.693
fixvar*comiter     0.000062  0.000031  0.000027    1.14  0.459
fixvar*array      -0.000030 -0.000015  0.000027   -0.54  0.684
fixvar*locremsv   -0.000054 -0.000027  0.000027   -0.99  0.504
filesize*splitsin -0.000045 -0.000023  0.000027   -0.83  0.559

Analysis of Variance for avtime6

Source               DF      Seq SS     Adj SS     Adj MS      F      P
Main Effects          7  0.00000028 0.00000028 0.00000004   3.38  0.397
2-Way Interactions    7  0.00000007 0.00000007 0.00000001   0.78  0.705
Residual Error        1  0.00000001 0.00000001 0.00000001
Total                15  0.00000036


 Nscores -
         -                                            *  G
         -
      1.2+                                      *    AC
         -                                     *    C
         -                                     *    AE
         -                                    *    D
         -                                   *    F
      0.0+                             **     A,AB
         -                          *    AD
         -                          *    AF
         -                         *    B
         -                        *    BD
     -1.2+                       *    AG
         -
         -    *    E
         -
           +---------+---------+---------+---------+------Effects
    -2.4E-04  -1.6E-04  -8.0E-05  0.000000  0.000080

A = fixvar    B = filesize  C = maxatom   D = splitsin  E = comiter
F = array     G = locremsv
```

1

Oct 6 1994 20:20:38 **ffd6s.lis** Page 1

```
MTB > #compare standard deviation for operation ID 6
MTB > let c33=20*logten(c18/c19)
MTB > ffactorial c33=(fixvar-locremsv)2;
SUBC> eplot;
SUBC> effects c32.

Alias Information for Terms in the Model.
Totally confounded terms were removed from the analysis

fixvar*filesize + maxatom*comiter + array*locremsv
fixvar*maxatom + filesize*comiter + splitsin*locremsv
fixvar*splitsin + maxatom*locremsv + comiter*array
fixvar*comiter + filesize*maxatom + splitsin*array
fixvar*array + filesize*locremsv + splitsin*comiter
fixvar*locremsv + filesize*array + maxatom*splitsin
filesize*splitsin + maxatom*array + comiter*locremsv

Estimated Effects and Coefficients for C33

Term                  Effect      Coef  Std Coef t-value      P
Constant                         4.195     1.577    2.66  0.229
fixvar                 6.166     3.083     1.577    1.95  0.301
filesize               1.424     0.712     1.577    0.45  0.730
maxatom                3.524     1.762     1.577    1.12  0.465
splitsin              -2.773    -1.386     1.577   -0.88  0.541
comiter               -7.448    -3.724     1.577   -2.36  0.255
array                 -9.983    -4.992     1.577   -3.17  0.195
locremsv              -8.480    -4.240     1.577   -2.69  0.227
fixvar*filesize        5.887     2.943     1.577    1.87  0.313
fixvar*maxatom        -3.999    -2.000     1.577   -1.27  0.425
fixvar*splitsin        2.780     1.390     1.577    0.88  0.540
fixvar*comiter        -6.102    -3.051     1.577   -1.93  0.304
fixvar*array          -1.020    -0.510     1.577   -0.32  0.801
fixvar*locremsv        0.667     0.334     1.577    0.21  0.867
filesize*splitsin      2.080     1.040     1.577    0.66  0.629

Analysis of Variance for C33

Source                DF      Seq SS     Adj SS     Adj MS      F      P
Main Effects           7     1148.88    1148.88     164.13   4.12  0.363
2-Way Interactions     7      405.68     405.68      57.95   1.46  0.565
Residual Error         1       39.80      39.80      39.80
Total                 15     1594.36




 Nscores -
         -                                            *    A
         -
      1.2+                                            *    AB
         -                                      *    C
         -                                    *    AD
         -                                  *    BD
         -                                 *    B
      0.0+                         *    *    AF,AG
         -                     *    D
         -                  *    AC
         -             *    AE
         -         *    E
     -1.2+       *    G
         -
         -   *    F
         -
           --------+---------+---------+---------+--------Effects
                 -8.0      -4.0       0.0       4.0

A = fixvar    B = filesize  C = maxatom   D = splitsin  E = comiter
F = array     G = locremsv
MTB > noout
```

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```
^Z
```

1

E FILTER CLIENT/SERVER RATIO

Oct 6 1994 21:04:37 **a.lis** Page 1

```
MTB > #CLIENT/SERVER RATIO FOR FILTER
MTB > print c1-c24


 ROW            s6c1av0   s6c1av1   s6c1av2   s6c1av3   s6c1av4   s6c1av6

   1  0.775326             1.97519   0.16822  0.156383   0.54762  0.000201
   2  0.776693             2.28642   0.15292  0.125502   1.32696  0.000173
   3  0.416971             2.47425   0.15590  0.160109   0.65176  0.000354
   4  0.487858             2.08035   0.17789  0.171425   0.87166  0.000309
   5  0.710847             2.29392   0.14691  0.125570   0.48440  0.000280
   6  1.585742             2.48599   0.30412  0.135081   0.76006  0.000171
   7  0.497850             6.12856   1.21229  0.224426   1.06763  0.000237
   8  2.260922             3.59413   0.21367  0.146373   0.61538  0.000216


 ROW   s5c2av0   s5c2av1   s5c2av2    s5c2av3   s5c2av4    s5c2av6   s3c4av0

   1   0.82943   4.07933   0.82586   0.748058   1.23012   0.000535   4.68114
   2   0.77951   4.35895   0.55439   0.485278   2.37024   0.000346   2.92955
   3   2.33749   5.12417   0.57705   0.480860   1.64060   0.000706   1.63343
   4   1.25697   4.42884   1.08337   0.403314   1.30989   0.000556   1.95052
   5   2.07509   4.67750   0.95894   0.665512   1.75513   0.000452   5.34762
   6   1.27128   3.36841   0.79820   0.289459   1.05090   0.000539   1.78957
   7   0.77002   4.54538   0.55526   0.446256   1.23431   0.000544   1.57756
   8   0.97068   3.77157   0.70909   0.293577   2.90890   0.000676   1.76388


 ROW   s3c4av1   s3c4av2   s3c4av3   s3c4av4    s3c4av6   s2c5av0   s2c5av1

   1   10.0006   4.45187   2.56187   3.50702   0.000801   7.54478   14.2149
   2    7.5391   2.94968   1.68345   4.57120   0.000695   5.43608    9.8826
   3    8.6149   2.38608   1.41445   2.69501   0.001252   4.82920    9.3062
   4    9.5904   5.56560   2.44926   3.83967   0.001057   3.45046   11.3033
   5    6.8995   3.41806   1.98038   2.80873   0.000866   3.21487    9.6603
   6    7.1607   3.53247   0.58731   2.83531   0.000765   3.13571   10.8601
   7   10.3569   2.96123   0.76837   2.85573   0.001038   2.06989    9.8309
   8    7.5947   3.20845   0.59306   2.79094   0.000991   3.46319    8.9991


 ROW   s2c5av2   s2c5av3   s2c5av4    s2c5av6

   1   6.44867   2.69781   4.37106   0.000965
   2   5.47354   2.25857   5.99562   0.000885
   3   3.98757   1.72096   3.33168   0.001608
   4   6.96989   2.73426   5.36182   0.001217
   5   6.04681   2.40790   4.09192   0.001281
   6   8.80068   0.91022   5.00500   0.000927
   7   6.63650   1.40800   6.30745   0.001201
   8   2.71522   1.25855   3.63485   0.001244

MTB > noout
MTB > EXAMPLE BOX AND DOT PLOTS
MTB > #operation ID 1
MTB > boxplot c2 c8 c14 c20
MTB > dotplot c2 c8 c14 c20


               ..  : :              .                               .
             -------+---------+---------+---------+---------+---------s6c1av1
                  2.40      3.20      4.00      4.80      5.60      6.40

              .           .        .       . .  .   .           .
             -----+---------+---------+---------+---------+---------+-s5c2av1
                3.50      3.85      4.20      4.55      4.90      5.25

                 .  .     :                .            .     .    .
             -----+---------+---------+---------+---------+---------+-s3c4av1
                7.00      7.70      8.40      9.10      9.80     10.50
```

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```
               .  .   ...         .   .                             .
              -+---------+---------+---------+---------+---------+-----s2c5av1
              9.0      10.0      11.0      12.0      13.0      14.0

MTB > noout


MTB > #ONE-WAY ANOVA
MTB > oneway data in c27,levels in c28

ANALYSIS OF VARIANCE ON av1
SOURCE     DF        SS        MS        F        p
C28         3    133.84     44.61    10.27    0.000
ERROR      44    191.08      4.34
TOTAL      47    324.92
                                     INDIVIDUAL 95% CI'S FOR MEAN
                                     BASED ON POOLED STDEV
 LEVEL      N      MEAN     STDEV    -----+---------+---------+---------+-
     1      8     2.915     1.390     (-----*-----)
     2      8     4.294     0.547          (-----*-----)
     3      8     8.470     1.362                           (-----*-----)
     4     24     5.226     2.658                (---*--)
                                     -----+---------+---------+---------+-
POOLED STDEV =    2.084                  2.5       5.0       7.5      10.0
MTB > Plot c29*c30;
SUBC>   Symbol.
MTB > noout


MTB > plot resids1*fits1;
SUBC> .

          -                          *
 resids1 -                          *
          -                          *
          -                          *
      3.0+     *
          -                          2
          -                          2                          2
          -                          *                          *
          -     *       2
      0.0+              4       *                          *
          -     5       *       4                          *
          -     *       *       2                          2
          -                          2                          *
          -
     -3.0+                          6
          -
          -
            +---------+---------+---------+---------+---------+------fits1
          2.4       3.6       4.8       6.0       7.2       8.4
```

1

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```
MTB > #operation ID 2
MTB > dotplot c3 c9 c15 c21

               .
             .:. .   .                                            .
             ---+---------+---------+---------+---------+---------+---s6c1av2
             0.20      0.40      0.60      0.80      1.00      1.20

             .. .            .         .  .           .           .
             -----+---------+---------+---------+---------+---------+-s5c2av2
               0.60      0.70      0.80      0.90      1.00      1.10

               .        :   .   . .             .                 .
             -+---------+---------+---------+---------+---------+-----s3c4av2
           2.40      3.00      3.60      4.20      4.80      5.40

                .         .            .   .   ..  .             .
            +---------+---------+---------+---------+---------+-------s2c5av2
          2.4       3.6       4.8       6.0       7.2       8.4

MTB > Stack ( 's6c1av2') ('s5c2av2') ('s3c4av2') ('s2c5av2') ('av2');
SUBC>   Subscripts c32.


MTB > oneway data in c31,levels in c32,[store resids in c33[fits in c34]]

ANALYSIS OF VARIANCE ON av2
SOURCE     DF        SS        MS        F        p
C32         3    162.52     54.17    46.41    0.000
ERROR      28     32.68      1.17
TOTAL      31    195.20
                                     INDIVIDUAL 95% CI'S FOR MEAN
                                     BASED ON POOLED STDEV
 LEVEL      N      MEAN     STDEV    ---+---------+---------+---------+---
     1      8     0.316     0.366     (---*--)
     2      8     0.758     0.196       (---*---)
     3      8     3.559     1.005                    (---*---)
     4      8     5.885     1.867                               (--*---)
                                     ---+---------+---------+---------+---
POOLED STDEV =    1.080               0.0       2.0       4.0       6.0
MTB > plot c33 c34

 resids  -
         -                                                 *
         -
     2.0+                               *
         -
         -                                                 *
         -    *                         *                  *
         -       2                                         *
     0.0+    7  4                       2                  *
         -       2                      2                  *
         -                              *
         -                              *
         -
    -2.0+                                                  *
         -
         -
         -                                                 *
           +---------+---------+---------+---------+---------+------fit
         0.0       1.2       2.4       3.6       4.8       6.0
```

1

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```
MTB > Stack ('s6c1av3') ('s5c2av3') ('s3c4av3') ('s2c5av3') ('av3');
SUBC>   Subscripts c36.
MTB > #OPERATION ID 3
MTB > dotplot c4 c10 c16 c22


            :    .    .    . .     .                         .
         +---------+---------+---------+---------+---------+---------+-------s6c1av3
     0.120     0.140     0.160     0.180     0.200     0.220

              :          .    .  ..                 .       .
          -----+---------+---------+---------+---------+---------+---------+-s5c2av3
           0.30      0.40      0.50      0.60      0.70      0.80

              :   .               .      .       .          .  .
         +---------+---------+---------+---------+---------+---------+-------s3c4av3
      0.40      0.80      1.20      1.60      2.00      2.40

           .         .   .        .                .   .       ..
          -----+---------+---------+---------+---------+---------+---------+-s2c5av3
           1.05      1.40      1.75      2.10      2.45      2.80




MTB >
MTB > oneway data in c35,levels in c36,[store resids in c37[fits in c38]]

ANALYSIS OF VARIANCE ON av3
SOURCE     DF         SS        MS       F        p
C36         3    16.765     5.588    19.41    0.000
ERROR      28     8.062     0.288
TOTAL      31    24.827
                                   INDIVIDUAL 95% CI'S FOR MEAN
                                   BASED ON POOLED STDEV
 LEVEL      N      MEAN     STDEV  ----+---------+---------+---------+--
     1      8    0.1556    0.0323  (----*-----)
     2      8    0.4765    0.1623      (-----*----)
     3      8    1.5048    0.8010                     (----*-----)
     4      8    1.9245    0.6948                           (----*-----)
                                   ----+---------+---------+---------+--
POOLED STDEV =   0.5366              0.00      0.70      1.40      2.10
MTB > plot c37 c38

 resids3 -                                          *
         -                                          *
         -                                                      2
     0.70+
         -
         -                                          *           *
         -             *                                        *
         -             *                            *
     0.00+   8         3
         -             3                            *           *
         -
         -
         -                                                      *
    -0.70+                                          *           *
         -
         -                                          2           *
         -
           --------+---------+---------+---------+---------+---------+--------fit3
                0.35      0.70      1.05      1.40      1.75
```

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```
MTB > #operation ID 4
MTB > dotplot c5 c11 c17 c23



           .   .   .  .      .     .            .               .
          -+---------+---------+---------+---------+---------+-----s6c1av4
        0.48      0.64      0.80      0.96      1.12      1.28

           .    : .         .  .                 .              .
          -+---------+---------+---------+---------+---------+-----s5c2av4
        1.05      1.40      1.75      2.10      2.45      2.80

          .  :..                  .         .                   .
          ---+---------+---------+---------+---------+---------+---s3c4av4
          2.80      3.15      3.50      3.85      4.20      4.55

             .    .      .    .         .     .          .    .
          -------+---------+---------+---------+---------+---------s2c5av4
             3.60      4.20      4.80      5.40      6.00      6.60



MTB > Stack ('s6c1av4') ('s5c2av4') ('s3c4av4') ('s2c5av4') ('av4');
SUBC>   Subscripts c40.
MTB > oneway data in c39,levels in c40,[store resids in c41[fits in c42]]

ANALYSIS OF VARIANCE ON av4
SOURCE     DF         SS        MS       F        p
C40         3    73.502    24.501    45.89    0.000
ERROR      28    14.948     0.534
TOTAL      31    88.450
                                   INDIVIDUAL 95% CI'S FOR MEAN
                                   BASED ON POOLED STDEV
 LEVEL      N      MEAN     STDEV  ---------+---------+---------+-------
     1      8    0.7907    0.2865  (--*---)
     2      8    1.6875    0.6467        (--*---)
     3      8    3.2380    0.6760                  (---*--)
     4      8    4.7624    1.0854                            (---*--)
                                   ---------+---------+---------+-------
POOLED STDEV =   0.7307                   1.5       3.0       4.5
MTB > plot c41 c42

 resids4 -                                                       *
         -                                   *
         -                **                                     *
      1.0+
         -
         -     *          *                  *                   *
         -
         -     *                             *                   *
      0.0+     2          2
         -     3
         -     *          3                  4                   *
         -                *                  *                   *
         -
     -1.0+
         -                                                       *
         -                                                       *
         -
           ----+---------+---------+---------+---------+---------+--fits4
            0.80      1.60      2.40      3.20      4.00      4.80
```

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1

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```
MTB > #operation ID 6
MTB > dotplot c6 c12 c18 c24


            :       .    .     .           .       .            .
          ---+---------+---------+---------+---------+---------+---s6c1av6
      0.000175  0.000210  0.000245  0.000280  0.000315  0.000350

            .               .          ....                 .   .
          ---+---------+---------+---------+---------+---------+---s5c2av6
      0.000350  0.000420  0.000490  0.000560  0.000630  0.000700

             .     .  .    .          .  . .               .
          -----+---------+---------+---------+---------+---------+-s3c4av6
         0.00072   0.00084   0.00096   0.00108   0.00120   0.00132

              .  . .               .. . .                     .
          -----+---------+---------+---------+---------+---------+-s2c5av6
         0.00090   0.00105   0.00120   0.00135   0.00150   0.00165



MTB > Stack ('s6c1av6') ('s5c2av6') ('s3c4av6') ('s2c5av6') ('av6');
SUBC>   Subscripts c44.
MTB > oneway data in c43,levels in c44,[store resids in c45[fits in c46]]

ANALYSIS OF VARIANCE ON av6
SOURCE     DF        SS        MS        F        p
C44         3 0.0000040 0.0000013    49.72    0.000
ERROR      28 0.0000008 0.0000000
TOTAL      31 0.0000048
                                   INDIVIDUAL 95% CI'S FOR MEAN
                                   BASED ON POOLED STDEV
 LEVEL      N      MEAN     STDEV  -------+---------+---------+---------
     1      8  2.43E-04  6.62E-05   (--*--)
     2      8  5.44E-04  1.14E-04           (---*--)
     3      8  9.33E-04  1.85E-04                      (---*--)
     4      8  1.17E-03  2.38E-04                             (--*---)
                                   -------+---------+---------+---------
POOLED STDEV = 1.64E-04                 0.00035   0.00070   0.00105
MTB > plot c45 c46

         -                                                   *
 resids6 -
         -
         -                                        *
  0.00025+
         -
         -                    2
         -     *                                  2          2
         -     2                                  *          2
  0.00000+     *              4
         -     4                                  *
         -                    *
         -                                        2
         -                    *                              *
 -0.00025+                                        *          *
         -                                                   *
         -
           --+---------+---------+---------+---------+---------+----fits6
       0.00020   0.00040   0.00060   0.00080   0.00100   0.00120

MTB > noout


^Z
```

1

F FILTER LOCAL VS REMOTE DISK

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```
MTB > #FILTER: LOCAL VS REMOTE SERVER ACCESS
MTB > #operation ID 0
MTB > dotplot c1 c7


            .     :           .       .         .   .         .
          ---+---------+---------+---------+---------+---------+---lav0
          1.20      1.80      2.40      3.00      3.60      4.20
                .
                :  . .    .         .                       .
          -----+---------+---------+---------+---------+---------+-rav0
            1.00      1.50      2.00      2.50      3.00      3.50

MTB > Stack ('lav0') ('rav0') ('av0');
SUBC>   Subscripts c14.
MTB > oneway data in c13,levels in c14,[store resids in c15[fits in c16]]

ANALYSIS OF VARIANCE ON av0
SOURCE     DF        SS        MS        F        p
C14         1     3.542     3.542     4.10    0.062
ERROR      14    12.099     0.864
TOTAL      15    15.641
                                   INDIVIDUAL 95% CI'S FOR MEAN
                                   BASED ON POOLED STDEV
 LEVEL      N      MEAN     STDEV  --------+---------+---------+--------
     1      8    2.5030    1.0808                (---------*---------)
     2      8    1.5620    0.7485  (---------*---------)
                                   --------+---------+---------+--------
POOLED STDEV =   0.9296                  1.40      2.10      2.80
MTB > plot c15 c16

         -
 resids0 -     *                                              *
         -
         -
     1.0+                                                     *
         -                                                    *
         -
         -     *
         -                                                    *
     0.0+      *
         -     *                                              *
         -     3
         -     *
         -
    -1.0+                                                     2
         -
         -                                                    *
           ------+---------+---------+---------+---------+---------+fits0
              1.60      1.80      2.00      2.20      2.40      2.60

```

1

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```
MTB > #operation ID 1


MTB > dotplot c2 c8

              .
              :      .              ..  .                  .
           -------+---------+---------+---------+---------+---------lav1
                 5.0       6.0       7.0       8.0       9.0      10.0

             ..      ..    .                      .          .     .
           -+---------+---------+---------+---------+---------+-----rav1
          6.80      7.20      7.60      8.00      8.40      8.80

MTB > Stack ('lav1') ('rav1') ('av1');
SUBC>   Subscripts c18.
MTB > oneway data in c17,levels in c18,[store resids in c19[fits in c20]]

ANALYSIS OF VARIANCE ON av1
SOURCE     DF        SS        MS        F        p
C18         1      6.92      6.92     3.29    0.091
ERROR      14     29.42      2.10
TOTAL      15     36.34
                                   INDIVIDUAL 95% CI'S FOR MEAN
                                   BASED ON POOLED STDEV
 LEVEL      N      MEAN     STDEV  --------+---------+---------+--------
     1      8     6.350     1.863   (----------*---------)
     2      8     7.665     0.854                (----------*----------)
                                   --------+---------+---------+--------
POOLED STDEV =    1.450                  6.0       7.0       8.0
MTB > plot c19 c20

      4.0+
         -   *
 resids1 -
         -
         -
      2.0+
         -
         -   *                                                     2
         -   2                                                     *
         -
      0.0+
         -                                                         3
         -   *                                                     2
         -
         -   3
     -2.0+
         -
          --------+---------+---------+---------+---------+--------fits1
                6.50      6.75      7.00      7.25      7.50

```

1

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```
MTB > #operation ID2
MTB > dotplot c3 c9


             .      .      .      .  .    .              .   .
           -+---------+---------+---------+---------+---------+-----lav2
          0.70      1.40      2.10      2.80      3.50      4.20



            .                          .  .  .       .     ..    .
           -------+---------+---------+---------+---------+---------rav2
                0.30      0.60      0.90      1.20      1.50      1.80

MTB > Stack ('lav2') ('rav2') ('av2');
SUBC>   Subscripts c22.
MTB > oneway data in c21,levels in c22,[store resids in c23[fits in c24]]

ANALYSIS OF VARIANCE ON av2
SOURCE     DF        SS        MS        F        p
C22         1     7.293     7.293     8.51    0.011
ERROR      14    12.001     0.857
TOTAL      15    19.294
                                   INDIVIDUAL 95% CI'S FOR MEAN
                                   BASED ON POOLED STDEV
 LEVEL      N      MEAN     STDEV  -----+---------+---------+---------+-
     1      8    2.5215    1.2107                   (--------*-------)
     2      8    1.1712    0.4987   (--------*-------)
                                   -----+---------+---------+---------+-
POOLED STDEV =   0.9259                0.80      1.60      2.40      3.20
MTB > plot c23 c24

 resids2 -
         -                                                      *
         -                                                      *
      1.2+
         -
         -
         -  3                                                   *
         -  *
      0.0+  *                                                   *
         -  2                                                   *
         -
         -                                                      *
         -  *
     -1.2+                                                      *
         -
         -                                                      *
         -
          ----+---------+---------+---------+---------+---------+--fits
            1.25      1.50      1.75      2.00      2.25      2.50

```

1

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```
MTB > #operation ID 3
MTB > dotplot c4 c10


          . :           .     .           .    .              .
          ---+---------+---------+---------+---------+---------+---lav3
          0.60      1.20      1.80      2.40      3.00      3.60

             .           ..            .   .  .            .    .
         +---------+---------+---------+---------+---------+---------+-------rav3
      0.45      0.60      0.75      0.90      1.05      1.20



MTB > Stack ('lav3') ('rav3') ('av3');
SUBC>   Subscripts c26.
MTB > oneway data in c25,levels in c26,[store resids in c27[fits in c28]]

ANALYSIS OF VARIANCE ON av3
SOURCE     DF        SS        MS        F        p
C26         1     2.252     2.252     3.11    0.099
ERROR      14    10.127     0.723
TOTAL      15    12.378
                                   INDIVIDUAL 95% CI'S FOR MEAN
                                   BASED ON POOLED STDEV
 LEVEL      N      MEAN     STDEV  ------+---------+---------+---------+
     1      8    1.6538    1.1734               (----------*---------)
     2      8    0.9035    0.2644  (----------*----------)
                                   ------+---------+---------+---------+
POOLED STDEV =   0.8505                0.60      1.20      1.80      2.40
MTB > plot c27 c28

         -
 resids3 -                                                    *
         -
         -
      1.2+
         -                                                    *
         -                                                    *
         -   *
         -   *
      0.0+   3                                                *
         -   2                                                *
         -   *
         -
         -
     -1.2+                                                    3
         -
         -
          --+---------+---------+---------+---------+---------+----fits3
          0.90      1.05      1.20      1.35      1.50      1.65

```

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```
MTB > #operation ID 4
MTB > dotplot c5 c11


           .                   .             ...   .  .       .
          -+---------+---------+---------+---------+---------+-----lav4
        1.40      1.75      2.10      2.45      2.80      3.15

              :.:   .                              .            .
          -----+---------+---------+---------+---------+---------+-rav4
            2.70      3.00      3.30      3.60      3.90      4.20

MTB > Stack ('lav4') ('rav4') ('av4');
SUBC>   Subscripts c30.
MTB > oneway data in c29,levels in c30,[store resids in c31[fits in c32]]



ANALYSIS OF VARIANCE ON av4
SOURCE     DF        SS        MS        F        p
C30         1     0.757     0.757     2.33    0.149
ERROR      14     4.557     0.325
TOTAL      15     5.314
                                   INDIVIDUAL 95% CI'S FOR MEAN
                                   BASED ON POOLED STDEV
 LEVEL      N      MEAN     STDEV  ------+---------+---------+---------+
     1      8    2.5940    0.5705  (----------*----------)
     2      8    3.0292    0.5705             (----------*----------)
                                   ------+---------+---------+---------+
POOLED STDEV =   0.5705                2.40      2.80      3.20      3.60
MTB > plot c31 c32

         -                                                      *
         -
    0.80+
         - *                                                    *
 resids4 -
         - 2
         - 3
    0.00+
         -                                                      *
         -                                                      5
         - *
         -
   -0.80+
         -
         - *
         -
         -
          ------+---------+---------+---------+---------+---------+fits4
             2.640     2.720     2.800     2.880     2.960     3.040

```

1

1

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```
MTB > #operation ID 6
MTB > dotplot c6 c12


             .     .  ..          . .            .             .
         +---------+---------+---------+---------+---------+-------lav6
   0.00050   0.00060   0.00070   0.00080   0.00090   0.00100

             .  .       .  .         .         .        .     .
          -------+---------+---------+---------+---------+---------rav6
          0.000560  0.000640  0.000720  0.000800  0.000880  0.000960

MTB > Stack (’lav6’) (’av4’);

* ERROR * 2 is an illegal number of arguments.

MTB > Stack (’lav6’) (’rav6’) (’av6’);
SUBC>   Subscripts c34.
MTB > oneway data in c33,levels in c34,[store resids in c35[fits in c36]]



ANALYSIS OF VARIANCE ON av6
SOURCE     DF        SS        MS        F        p
C34         1 0.0000000 0.0000000     0.12    0.738
ERROR      14 0.0000003 0.0000000
TOTAL      15 0.0000003
                                   INDIVIDUAL 95% CI’S FOR MEAN
                                   BASED ON POOLED STDEV
 LEVEL      N      MEAN     STDEV  -------+---------+---------+---------
     1      8  7.33E-04  1.67E-04      (--------------*-------------)
     2      8  7.06E-04  1.46E-04  (--------------*--------------)
                                   -------+---------+---------+---------
POOLED STDEV = 1.57E-04                 0.000640  0.000720  0.000800
MTB > plot c35 c36

  0.00032+
         -                                                         *
 resids6 -
         -   *
         -
  0.00016+   *                                                     *
         -
         -   *
         -
         -                                                         2
  0.00000+   *
         -
         -   *
         -   *                                                     2
         -                                                         *
 -0.00016+   2
         -                                                         *
           +---------+---------+---------+---------+---------+------fits6
    7.05E-04  7.10E-04  7.15E-04  7.20E-04  7.25E-04  7.30E-04

MTB > noout


^Z
```

1

G Appendix C

H USER GUIDE

H.1 INTRODUCTION

There have been several files developed outwith the main applications in this project. A list of each file, along with its associated functions(minus variables) now follows:

H.2 *.c FILES

- `random.c`: This file will generate a random number when including the following two functions:

```
/* sets inital value for random number generator */
   set_random()

/* generates a random number according to previous call to set_random()*/
   random()
```

- `ipffuncs.c`

  Set of instrumented PF library functions which time specific PF operations by calling timers in the file `timer.c`:

```
/* collects PF configuration details for results files*/
   ipf_init_struct()

/* associated function and timer calls*/
   ipf_export()

/* associated function and timer calls*/
   ipf_open()

/* associated function and timer calls*/
   ipf_readAtom()

/* associated function and timer calls*/
   ipf_writeAtom()

/* associated function and timer calls*/
   ipf_close()

/* function to start recording server idle time*/
   ipf_start_server()

/* function to stop recording server idle time*/
   ipf_stop_server()

/* function to start recording compute time per atom*/
   ipf_start_server()

/* function to stop recording compute time per atom*/
   ipf_start_server()
```

```
/* prints outfile for each client/server process functioning*/
   ipf_print_results()
```

- `timer.c`: Functionality behind timers and initialising functions.

```
/* sets up results file with current configuration details*/
   init_info()

/* initialises time structure(containing, average time, no. of calls etc) */
/* for each PF operation */
   init_timer()

/* starts system timer */
   start_timer()

/* stops system timer and updates current time structure with various */
/* time attributes */
   stop_timer()

/* distributes results to appropriate outfiles */
   print_timer()
```

Each of the above files has an associated `*.h` file with specific declarations.

H.3 Executables

- `mmfwriter_fix`: Generates a serial file with fixed length atoms
- `mmfwriter_var`: Generates a serial file with variable length atoms
- `client/server`: Executables for client and server processes.

H.4 Shell Scripts

A number of application specific shell scripts have been written(`csh`). These scripts have the following format:

- `database/numerical/filter`: Scripts which contain the Fractional Factorial designs.
- `setup`: Sets up configuration according to FFD's.(limited! . . . see problems)
- `hydraexlocal.chp`: Configuration file for clients communicating with local servers.
- `hydraexremote.chp`: Configuration file for clients communicating with remote servers.

H.5 Problems

As mentioned earlier, the source for most of the following problems is likely to be in-appropriate I/O hints supplied in each test application.

- **PFD**: One of the main factors considered to have an effect on overall I/O performance is the type of PFD. Unfortunately I could not get PF to distribute a serial file using PFMULTI.

  When distributing a serial file containing variable sized atoms, certain atoms were lost during an INTERLEAVE distribution.

- **server timer**: A timer was placed in the file `server.c`, to time how long servers spent idle during configuation runs. Two functions, ipfstarttimer() and ipfstoptimer() did not record the expected times in the results outfiles.

References

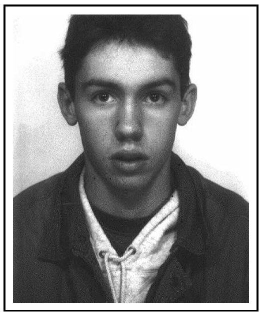
[Bruce R.A.A.,] Fletcher R.A. Trewin S. Smith G.A. Bruce R.A.A., Chapple S. Reuse, Portability and Parallel Libraries.

[Bruce R.A.A., 1993] MacDonald N.B. Trew A.S. Trewin S. Bruce R.A.A., Chapple S. CHIMP and PUL:Support for Portable Parallel Computing. 1993.

[Clarke L., 1993] Harding T. Clarke L. PUL-GF Parallel I/O Concepts. 1993.

[G.E.P.Box, 1978] J.S.Hunter G.E.P.Box, W.G.Hunter. Statistics for Experimenters. 1978.

[Ghosh J., 1993] Draper J.T. Ghosh J., Goveas K.D. Performance Evaluation of a Parallel I/O Subsystem for Hypercube Multicomputers. *Journal of Parllel and Distributed Computing*, 1993.



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