Understanding WHERE Clause Processing and Indexes
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Abstract
SAS® users can quickly access selected observations (rows) of data in SAS data sets using WHERE clause processing and indexes. This paper explores what an index is, the purpose of an index, how an index is created, factors that determine when an index is warranted, how WHERE clause processing can take advantage of an index, and techniques for tuning indexes for better performance. Attendees will learn valuable techniques for achieving improved query performance using indexes.

Introduction
Given the large number of books and articles on SQL, how strange it is not to find more material associated with indexes and WHERE clause processing. Certainly, these topics deserve special attention to assist SQL users’ better apply these powerful features in their programs, because good or bad usage can make all the difference in query outcomes.

Indexes can be used to improve the access speed to desired table rows. Rather than physically sorting a table (as performed by the ORDER BY clause or the BY statement in PROC SORT), an index is designed to set up a logical data arrangement without the need to physically sort it. This has the advantage of reducing CPU and memory requirements. It also reduces data access time when using WHERE clause processing. This paper presents elements essential to achieving a better understanding of indexes and their effect on WHERE clause processing.

Tables Used in Examples
The data used in all the examples in this paper consists of a selection of movies that I’ve viewed over the years, along with its actors. The Movies table consists of six columns: title, length, category, year, studio, and rating. Title, category, studio, and rating are defined as character columns with length and year being defined as numeric columns. The data stored in the Movies table is illustrated below.

MOVIES Table

<table>
<thead>
<tr>
<th>Title</th>
<th>Length</th>
<th>Category</th>
<th>Year</th>
<th>Studio</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brave Heart</td>
<td>177</td>
<td>Action Adventure</td>
<td>1995</td>
<td>Paramount Pictures</td>
<td>R</td>
</tr>
<tr>
<td>Candace</td>
<td>103</td>
<td>Drama</td>
<td>1992</td>
<td>MGM / UA</td>
<td>P6</td>
</tr>
<tr>
<td>Christmas Vacation</td>
<td>97</td>
<td>Comedy</td>
<td>1993</td>
<td>Warner Brothers</td>
<td>P6-10</td>
</tr>
<tr>
<td>Coming to America</td>
<td>116</td>
<td>Comedy</td>
<td>1998</td>
<td>Paramount Pictures</td>
<td>R</td>
</tr>
<tr>
<td>Daspa</td>
<td>130</td>
<td>Horror</td>
<td>1993</td>
<td>Columbia Pictures</td>
<td>R</td>
</tr>
<tr>
<td>Dress to Kill</td>
<td>105</td>
<td>Drama Mysteries</td>
<td>1988</td>
<td>Miramax Pictures</td>
<td>R</td>
</tr>
<tr>
<td>Forrest Gump</td>
<td>144</td>
<td>Drama</td>
<td>1994</td>
<td>Paramount Pictures</td>
<td>P6-13</td>
</tr>
<tr>
<td>Ghost</td>
<td>127</td>
<td>Drama Romance</td>
<td>1990</td>
<td>Paramount Pictures</td>
<td>P6-13</td>
</tr>
<tr>
<td>Harry</td>
<td>125</td>
<td>Action Adventure</td>
<td>1975</td>
<td>Universal Studios</td>
<td>P6</td>
</tr>
<tr>
<td>Jurassic Park</td>
<td>127</td>
<td>Action</td>
<td>1993</td>
<td>Universal Pictures</td>
<td>P6-13</td>
</tr>
<tr>
<td>Lethal Weapon</td>
<td>110</td>
<td>Action Crime &amp; Mobi</td>
<td>1997</td>
<td>Warner Brothers</td>
<td>R</td>
</tr>
<tr>
<td>Michael</td>
<td>106</td>
<td>Drama</td>
<td>1997</td>
<td>Warner Brothers</td>
<td>P6-13</td>
</tr>
<tr>
<td>National Lampoon's Vacation</td>
<td>98</td>
<td>Comedy</td>
<td>1983</td>
<td>Warner Brothers</td>
<td>P6-13</td>
</tr>
<tr>
<td>Petergeist</td>
<td>115</td>
<td>Horror</td>
<td>1992</td>
<td>MGM / UA</td>
<td>P6</td>
</tr>
<tr>
<td>Police Academy</td>
<td>120</td>
<td>Action Adventure</td>
<td>1978</td>
<td>MGM / UA</td>
<td>P6</td>
</tr>
<tr>
<td>Scarlett</td>
<td>170</td>
<td>Action Crime &amp; Mobi</td>
<td>1953</td>
<td>Universal Studios</td>
<td>R</td>
</tr>
<tr>
<td>Silence of the Lambs</td>
<td>116</td>
<td>Drama Suspense</td>
<td>1991</td>
<td>Clovis</td>
<td>R</td>
</tr>
<tr>
<td>Sin Wars</td>
<td>124</td>
<td>Action Sci-Fi</td>
<td>1977</td>
<td>Lucas Films Ltd</td>
<td>P6</td>
</tr>
<tr>
<td>The Hunt for Red October</td>
<td>135</td>
<td>Action Adventure</td>
<td>1990</td>
<td>Paramount Pictures</td>
<td>P6</td>
</tr>
<tr>
<td>The Wizard of Oz</td>
<td>104</td>
<td>Adventure</td>
<td>1933</td>
<td>MGM / UA</td>
<td>G</td>
</tr>
<tr>
<td>Titanic</td>
<td>134</td>
<td>Drama Romance</td>
<td>1997</td>
<td>Paramount Pictures</td>
<td>P6-13</td>
</tr>
</tbody>
</table>

The data stored in the ACTORS table consists of three columns: title, actor_leading, and actor_supporting, all of which are defined as character columns. The data stored in the Actors table is illustrated below.
**Understanding Indexes**

What exactly is an index? An index consists of one or more columns in a table to uniquely identify each row of data within the table. Operating as a SAS object containing the values in one or more columns in a table, an index is comprised of one or more columns and may be defined as numeric, character, or a combination of both. Although there is no rule that says a table must have an index, when present, they are most frequently used to make information retrieval using a WHERE clause more efficient.

To help determine when an index is necessary, it is important to look at existing data as well as the way the base table(s) will be used. It is also critical to know what queries will be used and how they will access columns of data. There are times when the column(s) making up an index are obvious and other times when they are not. When determining whether an index provides any processing value, some very important rules should be kept in mind. An index should permit the greatest flexibility so every column in a table can be accessed and displayed. Indexes should also be assigned to discriminating column(s) only since query results will benefit greatest when this is the case.

When an index is specified on one or more tables, a join process may actually be boosted. The PROC SQL processor may use an index, when certain conditions permit its use. Here are a few things to keep in mind before creating an index:

- If the table is small, sequential processing may be just as fast, or faster, than processing with an index
- If the page count as displayed in the CONTENTS procedure is less than 3 pages, avoid creating an index
- Do not to create more indexes than you absolutely need
- If the data subset for the index is not small, sequential access may be more efficient than using the index
- If the percentage of matches is approximately 15% or less then an index should be used
- The costs associated with an index can outweigh its performance value – an index is updated each time the rows in a table are added, deleted, or modified.

Sample code will be illustrated below on creating simple and composite indexes using the CREATE INDEX statement in the SQL procedure.

**Creating a Simple Index**

A simple index is specifically defined for one column in a table and must be the same name as the column. Suppose you had to create an index consisting of movie rating (RATING) in the MOVIES table. Once created, the index becomes a separate object located in the SAS library.

**SQL Code**

```sql
PROC SQL;
  CREATE INDEX RATING ON MOVIES(RATING);
QUIT;
```
SAS Log Results

PROC SQL;
   CREATE INDEX RATING ON MOVIES(RATING);
NOTE: Simple index RATING has been defined.
QUIT;

Creating a Composite Index
A composite index is defined for two or more columns in a table and must have a unique name that is different than the columns assigned to the index. Suppose you were to create an index consisting of movie rating (RATING) and movie category (CATEGORY) in the MOVIES table. Once the composite index is created, the index consisting of the two table columns become a separate object located in the SAS library.

SQL Code

PROC SQL;
   CREATE INDEX RATING_CAT ON MOVIES(RATING, CATEGORY);
QUIT;

SAS Log Results

PROC SQL;
   CREATE INDEX RATING_CAT ON MOVIES(RATING, CATEGORY);
NOTE: Composite index RATING_CAT has been defined.
QUIT;

Index Limitations
Indexes can be very useful, but they do have limitations. As data in a table is inserted, modified, or deleted, an index must also be updated to address any and all changes. This automatic feature requires additional CPU resources to process any changes to a table. Also, as a separate structure in its own right, an index can consume considerable storage space. As a consequence, care should be exercised not to create too many indexes but assign indexes to only those discriminating variables in a table.

Because of the aforementioned drawbacks, indexes should only be created on tables where query search time needs to be optimized. Any unnecessary indexes may force the SAS System to expend resources needlessly updating and reorganizing after insert, delete, and update operations are performed. And even worse, the PROC SQL optimizer may accidentally use an index when it should not.

Optimizing WHERE Clause Processing with Indexes
A WHERE clause defines the logical conditions that control which rows a SELECT statement will select, a DELETE statement will delete, or an UPDATE statement will update. This powerful, but optional, clause permits SAS users to test and evaluate conditions as true or false. From a programming perspective, the evaluation of a condition determines which of the alternate paths a program will follow. Conditional logic in PROC SQL is frequently implemented in a WHERE clause to reference constants and relationships among columns and values.

To get the best possible performance from programs containing SQL procedure code, an index and WHERE clause can be used together. Using a WHERE clause restricts processing in a table to a subset of selected rows. When an index exists, the SQL processor determines whether to take advantage of it during WHERE clause processing. Although the SQL processor determines whether using an index will ultimately benefit performance, when it does the result can be an improvement in processing speeds.
Conclusion
Indexes can be used to allow rapid access to table rows. Rather than physically sorting a table, an index is designed to set up a logical arrangement for the data without the need to physically sort it. Not only does this have the advantage of reducing CPU and memory requirements, it also reduces data access time when using WHERE clause processing. As was presented, by adhering to a few important rules about creating indexes, SAS users can use an index and a WHERE clause together to improve a query’s performance and processing speeds.

References
Lafler, Kirk Paul (1992-2005). PROC SQL for Beginners; Software Intelligence Corporation, Spring Valley, CA, USA.
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Acknowledgments
The author would like to thank Pablo J. Nogueras, Academic Chair and Clarence Jackson, Facilities Chair, for asking me to present at and to prepare this paper for SCSUG 2006. Thank you for a great conference!

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