The DS2 Procedure
SAS® Programming Methods at Work

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Contents

Preface ................................................................................................................................. vii
About This Book ................................................................................................................ ix
About The Author .............................................................................................................. xiii
Chapter 1: Solving Bigger Problems .................................................................................. 1
  big data. Big data. BIG DATA .......................................................................................... 1
  PROC DS2 ....................................................................................................................... 2
  Problem Space .................................................................................................................. 2
    Clarity ............................................................................................................................ 2
    Scope ............................................................................................................................. 2
    Modularity and Encapsulation .................................................................................... 3
  Data Types ...................................................................................................................... 4
  Data Space ..................................................................................................................... 4
    Embedded SQL ........................................................................................................... 4
    Threaded Data Access ............................................................................................... 4
    In-Database Processing .............................................................................................. 5
  Our First DS2 Programs .................................................................................................. 5
    PROC DS2 as a DATA Step Equivalent ...................................................................... 5
Chapter 2: Object-Oriented Programming for SAS Programmers .................................. 15
  Background and Definition ........................................................................................... 15
    Dog Class .................................................................................................................... 15
  An Example of OOP ...................................................................................................... 16
  Moving Forward ............................................................................................................. 20
Chapter 3: Variables and Data Types .............................................................................. 23
  Variable Names ............................................................................................................. 25
  DECLARE Statement .................................................................................................... 26
  DATA Step Conversion—Numerics .............................................................................. 27
  DATA Step Conversion—Characters .......................................................................... 28
Chapter 1: Solving Bigger Problems

big data. Big data. BIG DATA. .................................................................1
PROC DS2 ...............................................................................................2

Problem Space .......................................................................................2
Clarity .........................................................................................................2
Scope ...........................................................................................................2
Modularity and Encapsulation .................................................................3
Data Types ...............................................................................................4

Data Space ...............................................................................................4
Embedded SQL .........................................................................................4
Threaded Data Access ................................................................................4
In-Database Processing .............................................................................5

Our First DS2 Programs ..........................................................................5
PROC DS2 as a DATA Step Equivalent ....................................................5

big data. Big data. BIG DATA.

It seems that not a day goes by that we do not hear a familiar chant; even the most techno-Luddites
chant it—“big data. Big data. BIG DATA.” Although there is no doubt that the volumes of data are
growing, big data is the smaller of our problems. Yes, data are big, but how we handle
that big data is
an even bigger problem. If the problems that we have today were the same as the ones that we had 10
or even five years ago, our bigger and better hardware could easily handle them.

Today, we have far more complex problems. Today, the mega-retailer is no longer happy with data
about the profitability of a product by store. It wants to know who is buying what, when and where are
they are buying it, in what combinations are they buying it, and what can be offered at check-out to
increase the basket value. This is a complex problem, and bigger and better hardware does not solve it.
The complex and mercurial nature of today’s problems means that we have to develop complex yet
flexible solutions. How can we, as SAS developers, develop more complex and flexible solutions? One
way is to use PROC DS2.
The DATA step has served SAS programmers well over the years. Although it is powerful, it has not fundamentally changed since its inception. SAS has introduced a significant programming alternative to the DATA step—PROC DS2—a new procedure for your object-oriented programming environment. PROC DS2 is basically a new programming language based on the DATA step language. It is a powerful tool for advanced problem solving and advanced data manipulation. PROC DS2 makes it easier to develop complex and flexible programs for complex and flexible solutions. These programs are robust and easier to understand, which eases maintenance down the road.

Starting with SAS 9.4, PROC DS2 is part of the Base SAS package. For users in a high-performance analytics environment, there is PROC HPDS2. However, in this book, only PROC DS2 is discussed.

Problem Space

PROC DS2 deals with this more complex problem space by using many object-oriented programming (OOP) constructs. With OOP constructs, SAS programmers can develop more robust and flexible programs using the following:

- clarity
- scope
- modularity and encapsulation
- data types

Clarity

In DS2, you must be clear with each identifier that you are using. An identifier is one or more tokens or symbols that name programming language entities such as variables, labels, method names, package names, and arrays, as well as data source objects such as table names and column names. To ensure clarity, in DS2, identifiers are declared using a DECLARE statement. The DECLARE statement clearly states both the name and data type of the identifier. Before you can use an element in a DS2 program, you must tell DS2 the name and data type of the element. The benefit (besides making the programmer think more clearly about the nature of the program!) is that because the program does not compile if an invalid identifier is used, misspellings and other hard-to-detect errors can be addressed and corrected at the beginning.

Scope

In programming, scope is the area in which a variable is visible. In other words, scope lets you know where a variable can be accessed. In DS2, there are two levels of scope:

- global
- local

Global variables have global scope. That is, they are accessible from anywhere in the program. Local variables have local scope. That is, they are accessible only from within the block in which the variable
was declared and only while that block is executing. Each variable in any scope must have a unique name, but variables in different scopes can have the same name. This enables you to use consistent and meaningful variable names in different parts (or methods) of your program without overwriting values. The benefit is that you can more easily isolate worker variables (e.g., a DO loop variable, an intermediate calculation, etc.) from variables that will ultimately be written out to result sets.

**Modularity and Encapsulation**

A programming block is a section of a DS2 program that encapsulates variables and code. Programming blocks enable modularity and encapsulation by using modular and reusable code to perform specific tasks. This, in turn, can lead to shorter development time and the standardization of often-repeated or business-specific programming tasks. Layered programming blocks enable advanced encapsulation and abstraction of behavior, which enhances the readability and understandability of a program.

In addition, a programming block defines the scope of identifiers within that block. An identifier declared in the outermost programming block has global scope. An identifier declared in a nested block has local scope.

Table 1.1 lists some of the most common programming blocks, adapted from the *SAS 9.4 DS2 Language Reference Manual*.

**Table 1.1: Common Programming Blocks**

<table>
<thead>
<tr>
<th>Block</th>
<th>Delimiters</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Procedure</td>
<td>PROC DS2…QUIT</td>
<td></td>
</tr>
<tr>
<td>Data program</td>
<td>DATA…ENDDATA</td>
<td>Variables that are declared at the top of a data program have global scope within the data program. In addition, variables that the SET statement references have global scope. Unless you explicitly drop them, global variables in the data program are included in the program data vector (PDV). <strong>Note:</strong> Global variables exist for the duration of the data program.</td>
</tr>
<tr>
<td>Method</td>
<td>METHOD…END</td>
<td>A method is a sub-block of a data program, package, or thread program. Method names have global scope within the enclosing programming block. Methods contain all of the executable code. PROC DS2 has three system-defined methods: INIT(), RUN(), and TERM(). Variables that are declared at the top of a method have local scope. Local variables in the method are not included in the PDV. <strong>Note:</strong> Local variables exist for the duration of the method call.</td>
</tr>
<tr>
<td>Package</td>
<td>PACKAGE…ENDPACKAGE</td>
<td>Variables that are declared at the top of a package have global scope within the package. Package</td>
</tr>
</tbody>
</table>
variables are not included in the PDV of a data program that is using an instance of the package. **Note:** Package variables exist for the duration of the package instance.

### Thread

<table>
<thead>
<tr>
<th>Block</th>
<th>Delimiters</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thread</td>
<td>THREAD…ENDTHREAD</td>
<td>Variables that are declared at the top of a thread have global scope within the thread program. In addition, variables that the SET statement references have global scope. Unless you explicitly drop them, global variables in the thread program are included in the thread output set. <strong>Note:</strong> Thread variables exist for the duration of the thread program instance. They can be passed to the data program using the SET FROM statement.</td>
</tr>
</tbody>
</table>

### Data Types

Unlike the DATA step, which has two data types—numeric (double-precision floating-point) and fixed-length character—DS2 has many data types. This allows DS2 programs to interact better with external databases.

### Data Space

No surprise here, you have to deal with a big data space. DS2 helps you by providing three major features:

- embedded SQL
- threaded data access
- in-database processing

### Embedded SQL

DS2 can access data through a SET statement just like the DATA step. In addition, data can be accessed through embedded SQL statements.

### Threaded Data Access

DS2 can access data through a SET statement or through embedded SQL statements. DS2 also has threaded access to the data. The effectiveness of threaded access is determined, to a large extent, by how the back-end database manages threads.
In-Database Processing
If your data is in one of the supported databases, DS2 can process inside the database. This topic is not covered in this book.

Our First DS2 Programs
It seem de rigueur to start all programming language tutorials with a “Hello World” example. Because SAS developers are focused on real world problems and getting accurate results, let’s fast-forward and say “hello” to some simple data conversions.

PROC DS2 as a DATA Step Equivalent
Before you really take advantage of DS2, let’s look at a simple DATA step that creates a table, and then let’s look at the equivalent in DS2. The example data and program creates a SAS data set with data points representing temperatures in degrees Celsius. The following DATA step creates a SAS data set named dsDegC and uses parameters defined in the macro variables. One thousand observations (&NObs) are generated between -40 (&min) and 40 (&max). To verify that the DATA step and DS2 both create the same data, the seed value (&seed) is set to be passed into a random number generator.

Parameters

%let NObs = 1000;
%let min  = -40;
%let max  = 40;
%let seed = 123456;

DATA Step

data dsDegC (keep=degC)
   dsAvgC (keep=avgC)
;   
   label degC = 'Temp in Celsius';
   label avgC = 'Average Temp in Celsius';
   format degC F3.;
   format avgC F5.2;
   call streaminit(&seed);
   Min = &min; Max = &max;
   sum = 0;
   do obs = 1 to &NObs;
      u = rand("Uniform");               /* U[0,1] */
      degC = min + floor((1+Max-Min)*u); /* uniform integer in Min..Max */
      output dsDegC;
      sum = sum + degC;
   end;
   avgC = sum / (obs-1);
   output dsAvgC;
run;
The DS2 Procedure: SAS Programming Methods at Work

DS2

```sas
proc DS2 scond=error;
data ds2DegC_1 (keep=(degC) overwrite=YES)
  ds2AvgC_1 (keep=(avgC) overwrite=YES);
  declare integer degC having label 'Temp in Celsius' format F3.;
  declare double avgC having label 'Average Temp in Celsius' format F5.2;
method run();
  declare int min max obs;
  declare double u sum;
  streaminit(&seed);
  Min = &min; Max = &max;
  sum = 0;
  do obs = 1 to &NObs;
    u = rand('UNIFORM');               /* U[0,1] */
    degC = min + floor((1+Max-Min)*u); /* uniform integer in Min..Max */
    output ds2DegC_1;
    sum = sum + degC;
  end;
  avgC = sum / (obs-1);
  output ds2AvgC_1;
end;
enddata;
run;
quit;
```

The heart of the program, with the exception of the output data set name, is the same in both the DATA step and DS2.

```sas
do obs = 1 to &NObs;
  u = rand('Uniform');               /* U[0,1] */
  degC = min + floor((1+Max-Min)*u); /* uniform integer in Min..Max */
  output ds2DegC;
  sum = sum + degC;
end;
```

However, the DS2 program appears to be more complex, requiring more statements to get to the heart of the program.

1  DS2 is a new procedure in SAS 9.4 terminated by the QUIT statement. The scond=error option specifies that any undeclared identifiers should cause an error. There is also a new SAS option called DS2COND that can be set to ERROR. A best practice is to set DS2COND=ERROR in the configuration file so that it is always set.

2  Unlike the DATA step, DS2 does not automatically overwrite existing tables. The overwrite=YES data set option tells DS2 to drop the data set if it exists before creating it. This is standard in SQL.
3. All identifiers must be declared with a name and data type. The label and format are optional. The variables `degC` and `avgC` are declared outside of the method so they are global in scope. Only global variables can be written to the output tables.

4. All executable code must reside in a method. `method run()` is one of the system-defined DS2 methods.

5. `min`, `max`, and `obs` are integer variables. Because they are declared inside `method run()`, they are local in scope. Local variables are not written to the output tables.

The original DATA step has three distinct phases:

The first phase is initialization (setting the starting values):

```plaintext
call streaminit(&seed);  
Min = &min; Max = &max;  
sum = 0;  
```

The second phase is processing (executing the DO loop):

```plaintext
do obs = 1 to &NObs;  
   u = rand("Uniform");  
   degC = min + floor((1+Max-Min)*u);  
   output dsDegC;  
   sum = sum + degC;  
end;  
```

The third phase is termination (calculating the average):

```plaintext  
avgC = sum / (obs-1);  
output dsAvgC;  
```

In this simple DATA step, it is easy to enforce the one-time nature of the initialization and termination phases of the program. However, in many DATA steps, you must add programming logic to enforce these phases. DS2 simplifies and clarifies these phases.

**Initialization, Processing, and Termination**

DS2 simplifies and clarifies the three phases (initialization, processing, and termination) using three system-defined methods INIT(), RUN(), and TERM(). The first refinement of the DS2 program demonstrates this:

```plaintext  
proc DS2 scond=error;  
data ds2DegC_2 (keep=(degC) overwrite=YES)  
   ds2AvgC_2 (keep=(avgC) overwrite=YES)  
;  
declare integer degC having label 'Temp in Celsius' format F3.;  
declare double avgC having label 'Average Temp in Celsius' format F5.2;  
declare int min max NObs;  
declare double sum;  
retain sum nobs;  
```
method init();
    streaminit(&seed);
    Min = &min; Max = &max;
    nobs = &Nobs;
    sum = 0;
end;

method run();
    declare double u;
    declare int obs;
    do obs = 1 to NObs;
        u = rand('UNIFORM');
        degC = min + floor((1+Max-Min)*u);
        output ds2DegC_2;
        sum = sum + degC;
    end;
end;

method term();
    avgC = sum / nobs;
    output ds2AvgC_2;
end;
enddata;
run;
quit;

More variables now have global scope. They are no longer just inside a method and have only local scope. All three methods use global variables.

method init() is a system-defined method. It is automatically called at the start of the program. This replaces the if _n_ = 1 block that is common in many DATA steps. This method can be used to initialize variables and invoke processing.

method term() is a system-defined method. It is automatically called after method run() completes. It can be used to perform any wrap-up processing (in this case, calculating the average).

User-Defined Method

DS2 enables you to create your own methods to encapsulate logic. In the DS2 program, there is a formula (min + floor((1+Max-Min)*u)) that is used in more than one place. You can simply repeat the calculation. Or, even better, you can encapsulate the logic in a method. In this way, if you want to change the formula, you change it only once, as seen in the following example:

proc DS2 scond=error;
    data ds2DegC_3 (keep=(degC) overwrite=YES)
      ds2AvgC_3 (keep=(avgC) overwrite=YES)
    ;
declare integer degC having label 'Temp in Celsius' format F3.;
declare double avgC having label 'Average Temp in Celsius' format F5.2;
declare integer min max NObs;
declare double sum;
retain sum nobs;

method getRange(integer min, integer max, double u) returns integer; ❶
    return(min + floor((1+Max-Min)*u)); ❷
end;

method init();
    streaminit(&seed);
    Min = &min; Max = &max;
    nobs = &NObs;
    sum = 0;
end;

method run();
    declare double u;
    declare int obs;
    do obs = 1 to nobs;
      u = rand('UNIFORM');
      degC = getRange(min, max, u); ❸
      output ds2DegC_3;
      sum = sum + degC;
    end;
end;

method term();
    avgC = sum / nobs;
    output ds2AvgC_3;
end;
enddata;
run;
quit;

❶ getRange takes three positional arguments—two integers (min and max) and double u. It returns an integer value.

❷ The return statement sends the getRange method’s result to the caller. The formula is embedded in the return statement.

❸ The getRange method is invoked to calculate the degC value rather than using the formula directly.

Packages Make Methods Reusable
In the previous example, you saw how a method can be defined to replace a formula or algorithm that occurs in many places in a program. You can also define a method that can be invoked in many DS2
programs—this is called a package. In its simplest form, a package is a collection of related methods that is saved to a table that can be accessed by other DS2 programs.

```sas
proc DS2 scond=error;
package range /overwrite=YES;
  method getRange(integer min, integer max, double u) returns
  integer;
    return(min + floor((1+Max-Min)*u));
  end;
endpackage;
run;
quit;

proc DS2 scond=error;
data ds2DegC_4 (keep=(degC) overwrite=YES)
ds2AvgC_4 (keep=(avgC) overwrite=YES)
;
declare integer degC  having label 'Temp in Celsius' format F3.;
declare double avgC having label 'Average Temp in Celsius' format F5.2;
declare integer min max nobs;
declare double sum;
retain sum nobs;

declare package range range();

method init();
  streaminit(&seed);
  Min = &min; Max = &max;
  nobs = &NObs;
  sum = 0;
end;

method run();
  declare double u;
  declare int obs;
  do obs = 1 to nobs;
    u = rand('UNIFORM');
    degC = range.getRange(min, max, u);  
    output ds2DegC_4;
    sum = sum + degC;
  end;
end;

method term();
  avgC = sum / nobs;
  output ds2AvgC_4;
end;
enddata;
run;
quit;
```
A package is a collection of methods. Typically, the methods are logically related (for example, all of the methods are used to calculate a range of values). The package is saved to a table so that it can be used by other DS2 programs. In this example, the package is saved in the Work library. Once a package is tested and debugged, it is saved to a permanent library.  

PROC DS2 is invoked a second time to demonstrate the use of packages defined outside the PROC.  

All identifiers in a DS2 program need to be declared. In this line, an entity (variable) called range is declared. The range variable initiates an instance of a range package that was defined in a previous DS2 program. Although the variable range and the package range have the same name, it is not required.  

The getRange() method is called. It is in the range package referenced by the range variable.  

The previous examples demonstrate clarity, specifically because they separate processing steps into different methods—init(), term(), and getRange(). Furthermore, encapsulation is used; first, computational formulas are moved into methods. Second, methods are moved into a package that can be accessed by other DS2 programs.  

**Accessing Data—SET statement** 

In the following example, the table that was created in the previous example is read and a new data set is created. Temperatures are in degrees Fahrenheit.  

```plaintext
proc DS2 scond=error;
package conv /overwrite=yes;  
method C_to_F(integer C) returns double; /* convert degrees fahrenheit to degrees celsius */
   return 32. + (C * (9. / 5.));
end;

method F_to_C(double F) returns double; /* convert degrees fahrenheit to degrees celsius */
   return (F - 32.) * (5. / 9.);
end;
endpackage;
run;
quit;

proc DS2 scond=error;
data ds2DegF_5 (keep=(degF) overwrite=YES)
   ds2AvgF_5 (keep=(avgF) overwrite=YES)
;
declare double degF having label 'Temp in Fahrenheit' format F6.1;
declare double avgF having label 'Avg Temp in Fahrenheit' format F6.1;
declare double sum;
declare integer cnt;
declare package conv cnv();  
retain sum cnt;
```
method init();
  sum = 0;
  cnt = 0;
end;

method run();
  set ds2DegC_1;
  degF = cnv.C_to_F(degC);
  sum = sum + degF;
  cnt = cnt + 1;
  output ds2DegF_5;
end;

method term();
  avgF = sum / cnt;
  output ds2AvgF_5;
end;
enddata;
run;
quit;

A new package is created with temperature-conversion methods.
A new instance of the package is created and called cnv.
The table created in the previous example is read. The run() method iterates over all of the rows in the table.
The C_to_F() method is invoked.

Accessing Data—Threads
The last enhancement to this example shows how processing goes from sequential using the SET statement to concurrent using threads. You can use threaded processing on a single machine with multiple cores or parallel processing on back-end databases.

proc ds2;
  thread temps /overwrite=yes;
    method run();
      set ds2DegC_1;
    end;
  endthread;
run;
quit;

proc DS2 scond=error;
data ds2DegF_6 (keep=(degF) overwrite=YES)
  ds2AvgF_6 (keep=(avgF) overwrite=YES)
;
declare double degF having label 'Temp in Fahrenheit' format F6.1;
declare double avgF having label 'Avg Temp in Fahrenheit' format F6.1;
declare double sum;
A thread is created in the Work library. The `overwrite=yes` option deletes an existing thread of the same name if one exists.

The method `run()` iterates on the input data.

The thread must be declared before it is used.

DS2 launches four threads to read the data.
Index

A
accessing data 11–13, 81–86
ACCUMULATE() method 18
accumulator 17
ADD() method 19, 65, 81
adding data to Hash package 81
amt attribute 18, 19, 65
ANSI mode 40–41
arrays
assignment of 37–40
deferred dimensioning 35–36
dimensions of 36–37
temporary 34
variable 34–35
assignments
about 30–31
of arrays 37–40
ATTRIB statement 23
avgC variable 7
avgF variable 66

B
big data 1
BIGINT 24
BINARY() 24
Binary data types 24, 29
binding SQMSTMT 100
bindResults() method 83
bmi method 52
BY GROUP 92
by reference parameters 55–57
BY statement
SET statement with 89–92
SET statement with no 89
by value parameters 55

C
calling methods 79
CHAR() 24
Character data types 24, 28–29
clarity 2
classes
HAVING 34
ORDER BY 92
select 99
WHERE 84, 87–88, 89
cnt attribute 18, 19, 65
complete key 79, 80
completing declarations 80
constructor 64–65
conversion, of DATA steps 27–28, 28–29
C_to_F() method 12, 63

D
data
accessing 11–13, 81–86
adding to Hash package 81
big 1
complete key and 79
defining 80
options for SET statement 89
partial key and 79
types of 4, 23–42, 24
data() method 80
data sources
about 87–88
sample tables 88–89
SET statement 89–93
data space 4–5
DATA step
conversion of 27–28, 28–29
DS2 procedure as an equivalent to 5–13
FCMP procedure with functions in a 69
datasource parameter 79
DATE 24
Date data types 24, 29, 30
DECIMAL() 24
declarations, completing 80
DECLARE PACKAGE statement 79, 80
DECLARE statement 2, 23, 26–27, 34, 99
DECLARE THREAD statement 96
DECLARE TX statement 36
declaring Hash package 79
deferred dimensioning 35–36
defineData() method 80
defineKey() method 80
defining
  data 80
  keys 80
  methods 47–59
degC variable 7
degF variable 66
dimensioning, deferred 35–36
dimensions, of arrays 36–37
dot(.) notation 63
DOUBLE/FLOAT 24
drop command 84
DROP= option 89
DROP statement 45
DS2
  examples 75–86
  FCMP package with functions in 70–71
  methods, compared with FCMP procedure 71
DS2 procedure
  See also specific topics
  about 2
  as a DATA step equivalent 5–13
DS2COND option 24
duplicate parameter 79

E
Eberhardt, Peter 68
embedded SQL 4
encapsulation 3–4
end= option, SET statement 49
ENDTHREAD statement 96
examples
  DS2 75–86
  Hash package 78–81
  of object-oriented programming (OOP) 16–20
  TZ package 72–73

F
FCMP package 68–71
FCMP procedure
  compared with DS2 methods 71
  with functions 69
  with functions in a DATA step 69
FedSQL
  MERGE statement with as data source 95
  SET statement with data source as 92–93
fetch() method 83
find() method 81
firstOfMonth method 58
FORMAT statement 23, 26
forward reference 54–55
functions
  FCMP package in DS2 with 70–71
  FCMP procedure in a DATA step with 69
  FCMP procedure with 69
  IFC() 32–33
  IFN() 32–33

G
get methods 19
getAmt() method 65
getAvg() method 19, 65, 66
ggetCnt method 65
GETLOCALTIME method 71
getMax method 20
getMin method 20
GETOFFSET method 71
gerange() method 9, 11
GETTIMEZONEID method 71
GETTIMEZONENAME method 72
GETUTCTIME method 72

H
HASH object. See Hash package
Hash package
  adding data 81
  declaring 79
  example 78–81
  hashexp parameter 79
Hash/Hash iterator package 68
HAVING clause 34
HPDS2 procedure 2
HTTP package 68

I
identifier 2
IF DONE statement 49
IF operator 32–33
IF statement 51
IFC() function 32–33
IFN() function 32–33
IF/THEN statement 32–33
IN= option 89
in-database processing 5
inDate parameter 58
INFORMAT option 26
INQUERY option 26

L
identifier 2
INIT() method 3, 7–8, 44, 47, 77, 84, 98
initialization 7–8
INOUT statement 55
INPUT statement 87–88
instantiation 62–63
INTEGER 24
inToDate parameter 83
ISO 8601 date formats and functions 30
J
JSON package 68
K
KEEP= option 89
KEEP statement 45
keys, defining 80
L
LABEL option 26
LENGTH statement 23
Logger package 68
lookup and retrieval 81
M
Matrix package 68
MERGE statement
about 87–88, 93–95, 100
with FedSQL as data source 95
method parameter, packages as 67
method return variable, packages as 67
methods
about 3
ACCUMULATE() 18
ADD() 19, 65, 81
bindResults() 83
bmi 52
calling 79
C_to_F() 12, 63
data() 80
defineData() 80
definkey() 80
defining 47–59
fetch() 83
find() 81
firstOfMonth 58
forward reference 54–55
get 19
getAmt() 65
getAvg() 19, 65, 66
getCnt 65
GETLOCALTIME 71
getMax 20
getMin 20
GETOFFSET 71
getRange() 9, 11
GETTIMEZONENAME 71
GETTIMEZONENAME 72
GETUTCTIME 72
INIT() 3, 7–8, 44, 47, 77, 84, 98
modularity and 53–54
overloading 18, 51–53
packages and 9–11
REPLACE() 81
RUN() 3, 7–8, 12, 13, 44, 47, 49, 58, 76, 82, 98
scope and 57–59
setAmt 65
setCnt 65
system-defined 47–49
TERM() 3, 7–8, 19, 47, 98
thread 98
TOISO8601 72
TOLocalTIME 72
TOTIMESTAMPZ 72
TOUTCTIME 72
user-defined 8–9, 49–59
missing values 40–42
modularity
about 3–4
methods and 53–54
multidata parameter 79
N
naming variables 25–26
NCHAR() 24
NULL values 40–42
Numeric() 24
Numeric data types 24, 27–28
NVARCHAR() 24
O
object-oriented programming (OOP)
about 2
background of 15–16
defined 15
example of 16–20
future of 20–21
objects, packages as 64–67
OOP. See object-oriented programming (OOP)
operations 30–31
options
  DROP= 89
  DS2COND 24
  end= 49
  IN= 89
  INFORMAT 26
  KEEP= 89
  LABEL 26
  overwrite=yes 13
  RENAME= 89
  SCOND 24
  WHERE= 89
ORDER BY clause 92
ordered parameter 79
OUTPUT statement 98
overloading methods 51–53
overwrite=yes option 13

P
packages
  about 61
  instantiation 62–63
  as method parameter 67
  as method return variable 67
  methods and 9–11
  as objects 64–67
  scope and 67
  system-defined 68–73
  user-defined 61–67
  using package variables 63–64
parameterized threaded read 82–86
parameters
  datasource 79
  duplicate 79
  hashexp 79
  inDate 58
  inFromDate 83
  inToDate 83
  method 67
  multidata 79
  ordered 79
  by reference 55–57
  suminc 79
  thread 98–99
  by value 55
  partial key 79, 80
  PDV (Program Data Vector) 3, 44–45
problem space 2–4

procedures
  DS2 2, 5–13
  FCMP 69, 71
  HPDS2 2
processing 7–8
Program Data Vector (PDV) 3, 44–45
programming blocks
  common 3–4
  scope in other 45

Q
QUIT statement 6

R
recursion 59
RENAME= option 89
REPLACE() method 81
retrieval, lookup and 81
RETURN statement 9, 50
returning rows 100
rows, returning 100
RUN() method 3, 7–8, 12, 13, 44, 47, 49, 58, 76, 82, 98

S
SAS mode 40–41
saving tables 29
SCOND option 24
scope
  about 2–3, 43–44
  methods and 57–59
  in other programming blocks 45
  packages and 67
  Program Data Vector (PDV) 44–45
Secosky, Jason 68
select clause 99
SELECT statement 33–34, 93
SET FROM statement 4, 96
SET statement
  about 4, 11–12, 12–13, 82, 87–88
  Data set options 89
  end= option 49
  with FedSQL as data source 92–93
  with no BY statement 89
  with BY statement 89–92
setAmt method 65
setCnt method 65
SMALLINT 24
SQL, embedded 4
sqlstmt package 82–86
SQLSTMT package
  about 68, 99
  binding 100
  returning the rows 100

statements
  BY 89–92
  ATTRIB 23
  DECLARE 2, 23, 26–27, 34, 99
  DECLARE PACKAGE 79, 80
  DECLARE THREAD 96
  DECLARE TX 36
  DROP 45
  ENDTHREAD 96
  FORMAT 23, 26
  IF 51
  IF DONE 49
  IF/THEN 32–33
  IN_OUT 55
  INPUT 87–88
  KEEP 45
  LENGTH 23
  MERGE 87–88, 93–95, 100
  OUTPUT 98
  QUIT 6
  RETURN 9, 50
  SELECT 33–34, 93
  SET 4, 11–13, 49, 82, 87–93
  SET FROM 4, 96
  THREAD 96
  VARARRAY 34–35, 36
  VARARRAY OUT statement 36
  VARBINARY() 24
  VARCHAR() 24

suminc parameter 79

system-defined methods 47–49
system-defined packages 68–73

T
  tables
    sample 88–89
    saving 29
  temporary arrays 34
  temps variable 66
  TERM() method 3, 7–8, 19, 47, 98
  termination 7–8
  testing for missing or NULL values 41–42
  THREAD statement 96
  threaded data access 4
  threaded read
    about 82
    parameterized 82–86

threads
  about 12–13, 96–98
  methods 98
  parameters 98–99
  TIME() 24
  Time data types 24
  TIMESTAMP() 24
  TINYINT 24
  TOISO8601 method 72
  TOLOCALTIME method 72
  TOTIMESTAMPZ method 72
  TOUTCTIME method 72
  %TSLIT() macro 31
  TZ package
    about 68, 71–72
    example of 72–73

U
  Unicode UTF-8 29
  user-defined methods 8–9, 49–59
  user-defined packages 61–67

V
  values, missing and NULL 40–42
  VARARRAY OUT statement 36
  VARARRAY statement 34–35, 36
  VARBINARY() 24
  VARCHAR() 24
  variable arrays 34–35
  variables
    about 3
    avgC 7
    avgF 66
    data types and 23–42
    degC 7
    degF 66
    naming 25–26
    package 63–64
    temps 66

W
  WHERE clause 84, 87–88, 89
  WHERE= option 89
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Purpose
PROC DS2: SAS® Programming Methods at Work introduces a new SAS procedure. New in SAS 9.4, PROC DS2 provides programming concepts that can be used for the first time by many SAS programmers. Through examples, the book helps SAS DATA step programmers learn about PROC DS2 features such as data types, methods, packages, and threads.

Is This Book for You?
PROC DS2: SAS® Programming Methods at Work is for anyone interested in learning this new SAS procedure. This book explains the basic concepts from the ground up.

Prerequisites
PROC DS2: SAS® Programming Methods at Work assumes that the reader has at least a basic understanding of SAS DATA step programming.

Scope of This Book
PROC DS2: SAS® Programming Methods at Work covers the basic concepts of PROC DS2 so that DATA step programmers can quickly take advantage of the new procedure.

It discusses more advanced uses of PROC DS2 for high-performance procedures or in-database computing.

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PROC DS2: SAS® Programming Methods at Work was developed using the third maintenance release for SAS 9.4.

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