Macro Design Ideas: Theory, Template, Practice

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Abstract

Description : This paper provides a set of ideas about design elements of SAS® macros.

Purpose : This paper is a checklist for programmers who write or test macros.

Audience : advanced users or intermediate programmers polishing, testing, or writing macros.

Programs : in this paper are available on:

`http://www.sascommunity.org/wiki/Macro_Design_Ideas`

Keywords : macro design

Quote : Quality is free, but no one is ever going to know it if there isn't some sort of agreed-upon system of measurement.

— Philip Crosby: Reflections on Quality

Contents

Introduction

Overview

This section review the context in which macros are written.

Who? : Who writes macros? Either users or programmers write macros.

What? : What is a macro? A macro is a program which can replicate statements around values supplied in parameters.

Why? : Why write macros? These are some reasons to create macros.

1. reuse

2. encapsulate complexity

3. to use either of the macro statements `%do` or `%if`

4. to use either of the macro functions `%sysevalf` or `%sysfunc`

When? : When are macros written, or polished? Macros are written after ad hoc programming produces several examples of similar processing that can be simplified into a macro. Polishing is best accomplished before peer review.

Where? : Where are macros? Macros occur in these places:

- within a program

- in a program in a project

- in a site folder available to all projects

Summary

These ideas on macro design are for programmers writing or polishing macros for use in either a project or site.

Theory

Overview

Bricolage is the art of creative tinkering. Closely related is the idea of kludge: a workaround. Many macros start as kludges discovered whilst in bricolage.

The following topics are areas for further study and ideas for consideration during bricolage.

- Logic or Philosophy
- Quality
- Testing
- Vocabulary

Logic or Philosophy

Overview

One of the keys in design of a good macro is conditional processing. This section covers the historical development of logical reasoning from the 19th to the 20th century

- Boole: not, and, or, xor
- De Morgan: nand, nor
- Venn diagrams for s joins

Boole's Rules

George Boole is the author of rules now recognized as Boolean Logic, which are here reduced to three elements.

- unary operation
- binary operators
- precedence rules

unary : The unary operator is *not*. It flips or reverses its argument.

P	not
T	F
F	T

binary : In Boolean Logic there are two binary operators: *and*, and *or*. Each can be used to identify a particular combination of two values. In natural language we use the term *or* instead of the formal term *xor* meaning *exclusive or*. This operator is included in this definition for clarity in later discussions of Venn diagrams and sql (database) joins.

This is the truth table of the operators with De Morgan's extensions.

P	Q	and	or	derived: xor	De Morgan nand	nor
T	T	T	T			
T	F		T	T	T	
F	T		T	T	T	
F	F				T	T

Blanks here are False.

Notes:

- Notice that the *or* operator includes the rows identified by *and*

- Exclusive or (*xor*) is true when either one or the other, but not both, are true. Joins in sql identify each of the `xor` rows: xor(T,F) is `outer left`, xor(F,T) is `outer right`. De Morgan's `nand` includes both of the `xor` rows.

precedence : Parentheses have been added to the precendence list in acknowledgment of the recursive nature of logical resolution.

1. parentheses

2. negation

3. and

4. or

See also: SAS Operators in Expressions; and the SAS OnLine Documentation: operators, Boolean, _{page-title:} SAS Operators in Expressions.

! → The importance of parentheses in evaluations is addressed by De Morgan's definitions of *nand* and *nor*.

De Morgan's Laws Augustus De Morgan was a contemporary of Boole. De Morgan's Laws are stated in formal logic.

Conjunction means *and*; *disjunction* means *or*.

nand : The negation of a conjunction is the disjunction of the negations.
nor : The negation of a disjunction is the conjunction of the negations.

| operator	with parentheses				without parens		
nand	not(P	and	Q)	==	not P	or	not Q
nor	not(P	or	Q)	==	not P	and	not Q

! → Notice that the parentheses are necessary!

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Venn Diagrams for SQL Joins

John Venn was an English logician known for the visual representations of set theory known as Venn diagrams. SQL joins are understood more easily using Venn diagrams.

operator	sql	SAS	notes
and	inner join	intersect	compare nand
or	full outer join	union	
xor-left	left join	L except R	
xor-right	right join	R except L	caution!
nand	outer join		xor-left plus xor-right

Or This diagram illustrate Boole's logical operator *or(T,?)* which includes three sets: and(T,T), xor(T,F) and xor(F,T).
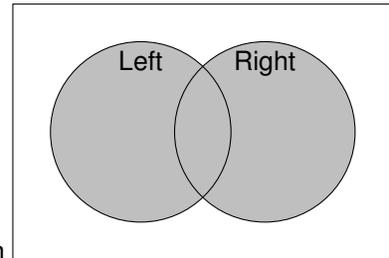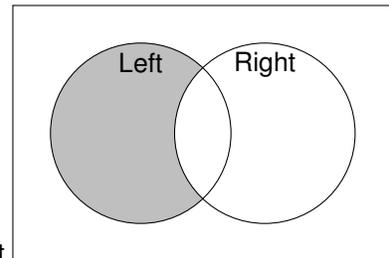
A or B: full outer join, union

And The logical operator *and(T,T)* identifies the row where both values are true.
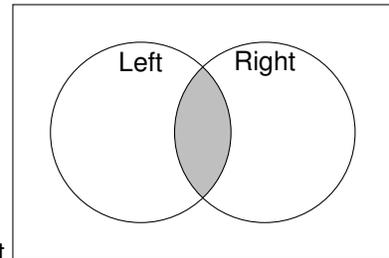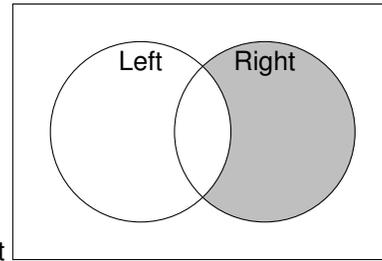
A and B: inner join, intersect

Xor.Left These diagrams illustrate the extensions of Boole's logical operator Exclusive Or which identifies two combinations: *xor(T,F)* and *xor(F,T)*.
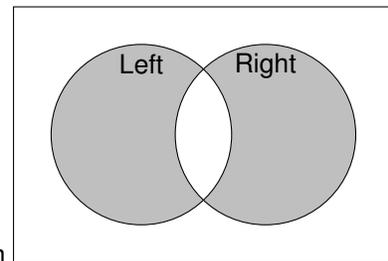
A xor B: left outer join, except

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Xor.Right

A xor B: right outer join, except

! → For a right outer join in SAS be sure to swap the Right table to the first position!

Nand: Xor This diagram illustrate De Morgan's logical operator: *nand*, which includes the two rows identified by *xor(T,?)*: xor-left and –right. Visually, this shows *not(and(T,T))*.

A xor B: outer join

Notes:
- See also SAS OnLine Documentation for the following pages:
- outer joins: _{page-title:} Creating and Using Outer Joins
- outer joins: full outer joins, _{page-title:} Selecting Data from More than One Table by Using Joins, contains Venn diagrams for inner (and) and outer (xor, xor-left) and full outer (or) joins
- outer union set operator, _{page-title:} query-expression

  discusses outer union, (inner) union, except and intersect
- Fehd, Evaluating Logical Expressions
- Lafler, Exploring DATA Step Merges and PROC SQL Joins

Summary Why do we need an understanding of logic? Because the macro `%if` statement is one of the reasons for writing a macro.

Quote Logic is an organized procedure for going wrong with confidence and certainty — Charles F. Kettering (1876-1958) American inventor, engineer, "Kettering's Law," from address before American Society of Mechanical Engineers (c. 1944)

Quality

Overview

Quality is an elusive concept. We use adjectives such as 'good' and 'high' to modify 'quality'. But quality assurance is simple: does the product conform to the specifications? This section reviews authors who defined our sense of quality, first quality control, and later quality assurance.

- Pareto
- Shewart
- Deming
- Juran
- Crosby

Pareto

Vilfredo Pareto, an Italian economist, wrote in 1906 that 80% of the land in Italy was owned by just 20% of the population. This idea was named a rule in the 1940s by quality managment consultant J. M. Juran who popularized it with the slogan: "the vital few and trivial many". The essence of the idea is that focusing on a few key elements produces the greatest return. In most real-world examples the numbers are not exactly 80/20 but may be 70/30 or 90/10; and their sum does not have to equal 100%.

See Juran's reframe of 'trivial many' to 'useful many' below.

Shewart

Walter A. Shewhart is often referred to as the father of statistical quality control based on a memo he wrote while working at Western Electric Company in 1924 which separated assignable-cause (signal) from chance-cause (noise).

Here are his data presentation rules:

- Data have no meaning apart from their context.
- Data contain both signal and noise. To be able to extract information, one must separate the signal from the noise within the data.

Notes:
- Shewart is the author of the acronym PDCA: Plan-Do-Check-Act.
- Deming noticed Shewhart's publication in 1938 and reframed his own vocabulary about measurement error to the terms used by Shewhart.
- See also: SAS documentation for the Shewart and Ishikawa procedures.

quote:
- Information is *the* difference
  that makes *a* difference

  — Gregory Bateson, 1904–1980, Steps to an Ecology of Mind, 1972

Deming

W. Edwards Deming and Juran were contemporaries in the 1940s and 50s; both consulted with Japanese companies during the post-war period. Deming is considered more practical for his focus on statistical process control. Deming's famous quotation is:

1. When people and organizations focus primarily on quality, defined by the following ratio,

$$Quality = \frac{Results\ of\ work\ efforts}{Total\ costs}$$

quality tends to increase and costs fall over time.

2. However, when people and organizations focus primarily on costs, costs tend to rise and quality declines over time.

Deming reframed Shewart's acronym PDCA: Plan-Do-Check-Act

to PDSA: Plan-Do-Study-Act.

Juran

Joseph M. Juran is famous for reframing Pareto's phrase "the vital few and the *trivial* many" to: "the vital few and the *useful* many". His emphasis during his consulting work in Japan in the 1950s was on educating managers about their cultural concepts of quality. This is Juran's trilogy for managers:

- quality planning
- quality control
- quality improvement

Juran brought Kaoru Ishikawa's concept of quality circles to the U.S.

Crosby

Philip B. Crosby is the author of the sound bytes:

- Zero Defects
- Quality is Free
- Do it Right the First Time

Here are his four major principles:

1. The definition of quality is conformance to requirements (requirements meaning both the product and the customer's requirements).
2. The system of quality is prevention.
3. The performance standard is zero defects (relative to requirements).
4. The measurement of quality (the cost) is the price of nonconformance.

Summary

Why do we need an understanding of quality assurance? Because managerial support for documentation and specifications are necessary when writing macros.

Testing

Overview

Fred Brooks in his book, The Mythical Man Month, provides the following table which describes how much time was spent on testing during development of the operating system for the IBM OS/360 during the 1960s.

Phase	Time	Action	Time
Design	1/2	Understand Problem:	1/3
		Education and Research	
		Development Coding	1/6
Testing	1/2	Component or Unit Test	1/4
		Systems or Integration Test	1/4

! → Note the difference between debugging, which occurs during development, and testing which occurs afterwards.

Basics

Two decisions are needed in order to write testing statements in a macro.

- name of macro variable, recommended: testing, default = 0==false

- information useful during testing: data structure

```
%macro demo_testing
        (testing=0);
%*reset testing: add value of global testing option(s);
%let testing = %eval(   &testing
                    or %sysfunc(getoption(mprint)) eq MPRINT);
%*...;
%if &testing %then %do;
    PROC sql; describe table &syslast;
              quit;
    %end;
```

The describe table statement writes the data structure to the log.

The contents and datasets procedures can be used as well; their output is written to the output window.

```
PROC Contents data = &syslast;
PROC Datasets library = work;
              contents data = &syslast;
              quit;
run;
```

Varieties

The varieties of testing experience are described by

Fehd [11, nesug2007.cc12]; see also: Writing Testing-Aware Programs.

Summary

Why do we need an understanding of software testing?

Because testing takes up half our budget!

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Vocabulary

Overview

A discussion of vocabulary and assumptions is a necessary precursor to effective communication during project development. This section reviews a few items that macro writers ought to agree on.

- program types
- SAS types
- naming conventions
- style guide

! → This story illustrates just how different corporate cultures can be.

> The $125 million Mars Climate Orbiter crashed on the planet because the Jet Propulsion Laboratory used metric units, while engineers at Lockheed Martin used feet and pounds.

Program Types

These are theoretical types and their definitions are exclusive.

1. module: top level, calls routines and subroutines
2. routine: middle level, calls other routines and subroutines
3. subroutine: lowest level, no calls

The author offers the recommendation that SAS programs have three levels, and in extraordinary circumstances a maximum of four. Having more levels in one program increases the complexity of testing and identifying the source of problems.

SAS Types

Program types in SAS are not so definitive as the theoretical types. These definitions are non-exclusive and therefore may overlap.

1. program: has multiple steps, either data or procedure
2. parameterized %include, is a program with one or more global macro variables in the calling program which act as parameters
3. macro: replicates one or more statements or steps
4. macro function: is a subroutine, returns one or more tokens within a statement

Naming Conventions

Refer to the Style Guide item on capitalization to determine whether to use lowcase with underlines or InitCaps to differentiate global from local macro variables.

Style Guide

A Style Guide is a list of preferences for the following items:

- capitalization: lowcase, InitCaps, UPPERCASE
- indentation: tab, 2, 3, 4, 8 spaces
- line width maximum
- naming conventions
- white space

! → This is the author's style guide

- capitalization: see also naming conventions
    - **–** lowcase is the default
    - **–** use under_lines for nouns
    - **–** UPCASE: AVOID! ALL CAPS IS HARD TO READ!
- indentation: data: 3, macros: 4
  replace tabs with spaces to ensure consistent printing
- line width maximum: 72; ensures cross platform compatibility
- one semicolon per line, maximum
- white space between tokens: use to align items for comparison

---

Why Capitalization Rules?

This story is from the 1980s when printers were 9-pin dot-matrix.

```
compare capital eye   I
        with lower case  el
```

I once programmed a system that came to me with a five-year-old bug. The value of a key data element — shrinkage in the customer's inventory — always came back zero. . . . The code logs showed that six programmers before me had failed to fix the bug. . . . One day, after some eight weeks of searching, I . . . saw the reason for the zero. . . . a simplified explanation is that the code read:

`key_data_element=I_value`   (capital *I* (eye), which had been initialized to zero),
                                    when it should have read:
`key_data_element=l_value`   (lower-case *L* (el),   holding the real value).

Now this is truly awful programming. No variables should be given such similar names, especially not when their sole differentiator is two letters nearly identical visually. Six programmers before me, looking at code on our white-on-green character screens,
could not tell *eye* from *el*.   —Ellen Ulman, Printing, in Wired magazine April 16, 2013.

Summary

The primary purpose of documentation is that it is read and understood by both its creators and users before and after release. A common vocabulary — both stylistic and visual — is necessary for effective communication because readability is the first requirement for reuse.

Templates

Overview

In this section we review the parts of a model macro.

1. documentation
2. macro

Documentation

Overview

The primary audience of documentation is for colleagues before and during peer review. Secondarily, good documentation is the best advertising of the macro for users. Finally, readability is a requirement for reuse.

- identify: name and author
- information:
  - summary
  - contexts
  - specifications
- example
- notes

identify : write a generic *file-specification*

```
/*      Name: <UNC>\SAS-site\macros\callmacr.sas
        Author: Claude Shannon  1963
```

information : This is advertising that the macro has a design.

```
Summary       : description  : does what to which?
                purpose      : used when, where?
Contexts      : program group: data cleaning, ???
                program  type: routine|subroutine
                SAS      type: macro
                uses routines: ...
Specifications: input  : required:
                         optional:
                process:
                output :
```

examples : If at all possible provide an example, with data sets from the libref sashelp, that will work with no initialization.

```
Usage Example:
PROC freq data = sashelp.class;
```

Show output from the example: notes in log or listing.

Example

This is the documentation of Fehd [9, sco.Macro-CallMacro].

```
                            ───── callmacr.sas ─────
1    /*       Name: <UNC>\SAS-site\macros\callmacr.sas
2          Author: Ronald J. Fehd  2012, 2013, 2014
3          -------------------------------------------------------
4    Summary       : description  : call macro using
5                                   all values in data set row as parameters
6                    purpose      : provide generic method to call macro
7                                   using list::control data set of parms
8                    -------------------------------------------------------
9    Contexts      : program group: list processing token generator
10                   program  type: routine
11                   SAS       type: macro function
12                   uses routines: macro named in the parameter macroname
13                   -------------------------------------------------------
14   Specifications: input  : required: Data, MacroName
15                            optional: MacroParms, Hex16
16                   process: assemble macro-call, call
17                   output : from MacroName
18                   -------------------------------------------------------
19   Parameters    : Data      = one- or two-level data set name
20                   ,MacroName = name of macro to call
21                   ,MacroName = put :: default, for testing
22                   ,MacroParms = additional parameters for called macro
23                                 *-Constraint-*: must be enclosed in nrstr:
24                   ,MacroParms = %nrstr(data=sashelp.class,var=Sex)
25                   ,Hex16     = 1 :: default, convert numerics to hex16
26                                 used to pass real numbers accurately
27                                 across step boundaries
28                   ,Hex16     = 0 :: pass numerics as decimals
29                   ,Semicolon  = 0 :: no semicolon after macro call
30                   ,Semicolon  = 1 :: use when macroname is a statement
31                                 note: auto-reset when macroname=put
32                   ,Testing    = 0 :: default, no extra messages in log
33                   ,Testing    = 1 :: for testing, note: auto-reset when
34                                 options mprint source2;
35                   -------------------------------------------------------
36   Bells,Whistles: writes real time used to log
37                   note: CALLMACR used real time  0:00:00.016
38   ----------------------------------------------------------------------
39   Usage Example:
40   PROC freq data   = sashelp.class;
41           tables    sex
42                    / noprint
43             out =      work.freq_class_sex;
44   run;*necessary;
45   %callmacr(data       = work.freq_class_sex
46           ,macroname  = put note:
47           ,macroparms = %nrstr(data=sashelp.class,var=sex)
48           )
49   log:
50   note:(data=sashelp.class,var=sex
51       ,Sex=F,COUNT=4022000000000000,PERCENT=4047AF286BCA1AE7)
```

Summary

Good documentation is essential to two groups of people:

- colleagues reading before and during peer review,
  when the majority of errors can be found

- users who want to know how to use the macro

! → • remember: readability promotes reuse

- see also: Rhodes [17, sgf2013.Programming-Standards]

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A Macro

Overview

A macro is similar to a data step:

both contain compile and execution (run-time) statements.

Data Step

A data step has two sets of statements:

- compiler directives which describe the data structure
- execution statements which implement the algorithm

```
* compiler directives: create input buffer and PDV;
DATA data-set-name
    (label = 'the new stuff');
    * define new variables;
    attrib VarB length = <$> 4
                 label  = 'describing Var B';

* execute algorithm: assignment(s);
do until(endofile);
   set libref.data-set-old
       end = endofile;
   * assignments;
   output;
   end;
stop;
run;
```

Macro   Macros have a similar set of compile and execute statements:

- compile:
  - name
  - parameters
  - description
  - local
- execute:
  - assignments
  - assertions: `%if`
  - program: `%do`

name : The name of the macro can provide answers to the question:

Does what action on which object?

The simplest idea is to use a verb and an object in the name. The verb names the process; the noun may be either the input or the output.

parameters : Use parameter names that echo their usage in the program; if at all possible provide default values for unit testing.

description : Provide a description, which shows up in the `catalog` procedure output, that indicates where the macro resides: project or site, and what it does, adding more information than the macro name.

local : The macro may require temporary variables.

assignments : In support of testing a macro may standardize parameter values and logically add values from options. In a user-friendly macro a data set name may be one- or two-level; if assertions need two macro variables then recode.

assertions : If parameter values are invalid then exit gracefully.

See also: Fehd [7, sco.Cond-Exec-Global-Stmnts]

Template for a Macro

```
%macro sort_by_category
        (data    = sashelp.class
        ,by      = sex
        ,out     = work.sorted /* may be one_level or two.level */
        ,testing = 0
        )
/ /* ** store source /* */
  des = 'site: this macro does ...';
%***** allocate temp var names;
%local out_lib out_data;

%*** assignments;
%let data = %lowcase(&data);
%let out  = %lowcase(&out);
%let out_lib  = work;
%let out_data = &out;
%** if out is a two-level name (has dot) then split;
%if %index(&out,.) %then %do;
    %let out_lib  = %scan(&out,1,.);
    %let out_data = %scan(&out,2,.);
    %end;
%** reset: add options info to var testing;
%let testing = %eval(not(0 eq &testing)
                    or %sysfunc(getoption(mprint))
                              eq %upcase(mprint));
%** assertions;
%if not %sysfunc(exist(&data)) %then %do;
    %put %str(ER)ROR: %sysmacroname &data not exists;
    %return; %* RETURN means jump to mend;
            %* see also %goto exit;
    %end;
%** !NOTE!:LIBREF function returns 0 if libref has been assigned;
%if %sysfunc(libref(&out_lib)) %then %do;
    %put %str(ER)ROR: %sysmacroname libref of &out not assigned;
    %goto exit;
    %end;
%if %sysfunc(exist(&out)) %then %do;
    %put Note: %sysmacroname &out was overwritten;
    %end;
PROC sort data = &data
          out  = &out;
          by     &by;
%if &testing %then %do;
    PROC sql; describe table &syslast;
              quit;
    %end;
%exit: %* destination == label of %goto;
run;
%mend <macro-name>;
```

Practice: Tricks or Traps

Overview

This section provides examples of common construction items and provides examples of solutions.

- evaluating Oregon
- reducing choices to boolean
- time-used note

Evaluating ORegon

The two-letter postal code abbreviation of the U.S. state named Oregon is OR, which is a logical operator.

The simple test of the value fails because the value is interpreted as a logical operator.

```
%if &state eq OR ...
%*is expanded to:;
%if OR eq <missing> OR ...
```

The solution is to quote the strings:

```
%if "&state" eq "OR" %then ...
```

See also: Fehd [5, sco.Beginners-Tour].

Reduction to boolean

Many problems arise in logical evaluation of expressions which contain user-supplied values written in natural language. Examples for boolean values include: yes/no, true/false, positive/negative, etc. Further complications come from allowing case variations: lowcase, Propcase, or UPCASE.

The problem can be shown as:

```
%if    &condition eq y    or &condition eq Y
   or &condition eq yes  or &condition eq Yes
   or &condition eq YES %then ...
```

One solution is to use the macro `in` operator

```
%macro chk_this(condition=0)/minoperator;
%if %eval(&condition in y Y yes Yes YES)
    %then ...
```

The author's solution is to standardize the case, reduce to the first letter and recode.

```
                        callmacr.sas
1  %if not(   &choice eq 0
2         or &choice eq 1) %then
3     %let choice=%eval(y eq %lowcase(%substr(&choice,1,1)));
4
5  %* compare to the radical solution: any response is True=1;
6  %let choice=%eval(not(0 eq &choice));
```

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Time-used Note   A macro function does not return steps, so there are no timing notes writ-
ten in the log. For a macro function containing a `%do` loop the following
statements can be added to write an elapsed time-used note.

This trick requires local macro variables for the subtraction at the end of the
routine. This code shows the initialization at the top of the definition.

```
%local time_start time_end;
%let   time_start = %sysfunc(datetime(),hex16.);
```

This is the calculation at the bottom of the definition.

```
%let time_end = %sysfunc(datetime(),hex16.);
%put note: &sysmacroname used real time %sysfunc
           (putn(&time_end.x-&time_start.x,time12.3));
%mend;
```

Notes: • initialize: save system datetime as hex16

$$\text{time\_start} := \text{'1234567890abcdef'x}$$

• termination $\text{time\_end} := \text{'12345678facebook'x}$

difference: $\text{time\_used} := \text{time\_end} - \text{time\_start}$

convert real number to user-readable hours minutes and seconds:
hh:mm:ss.sss

$$\text{putn(\&time\_used,time12.3)}$$

Summary

Conclusion   The primary purpose of a macros is to hide complexity.

A good macro is the result of several ideas coming together:

• First is management support for quality assurance and a style guide.

• Next is design, which leads to good documentation and programming.
This produces a macro ready for peer review and testing.

• Finally, readability of documentation, and program, promotes reuse.

Further Reading	programs :	for this paper are in Macro Design Ideas
	peer review :	Rhodes [17, sgf2013.Programming-Standards]
	predecessor :	Fehd [12, sgf2008.003] (SmryEachVar) developed a suite of programs to return a list of the frequencies of each variable in a data set or libref. This suite illustrates the three levels of program complexity: module, routines, and subroutines. Programs for SmryEachVar are here: Fehd [8, sco.SmryEachVar].
	quality :	Crosby [3, Crosby-Quality-and-Me] and Crosby [2, Crosby-Quality-is-Free]
		Deming [4, Deming-Out-of-the-Crisis]
		Juran [13, Juran-Architect-of-Quality]
	! →	Quality assurance is different from quality control.
	style guides :	Celko [1, Celko.2005-SQL-programming-style]
		This paper was typeset using the TEX program developed by Donald Knuth and illustrated in Knuth [14, Knuth:Literate-Programming]
		Martin [15, Martin.2009-Clean-Code]
		McConnell [16, McConnell.2004-Code-Complete-2e]
	examples :	One of the best ways to learn to design and write macros is to examine other people's work.
	list :	Jiantang Hu wrote a blog entry with a list of macro collections.
	Berry :	Roland Rashleigh-Berry has a list of macros that he has developed for clinical reporting. He has good notes on avoiding name collisions.
	Devenezia :	Richard A. DeVenezia has a page with his macros.
	Fehd :	Many of the author's macros are on sas.community.org:
		Fehd [10, sco.Macro-Loops-With-Dates] is in this conference proceedings. Fehd [9, sco.Macro-CallMacro] is the example documentation shown here.
		This program may be useful: Fehd [6, sco.Indexing-Programs]
	Friendly :	Michael Friendly has a suite of macros which have internal markup symbols so that they can be processed and an html page extracted from them.
	Schick :	Arnold Schick of University of Marburg, Germany, has a collection of macros.

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Technical skill is mastery of complexity

while creativity is mastery of simplicity.

— E. C. Zeeman, British mathematician