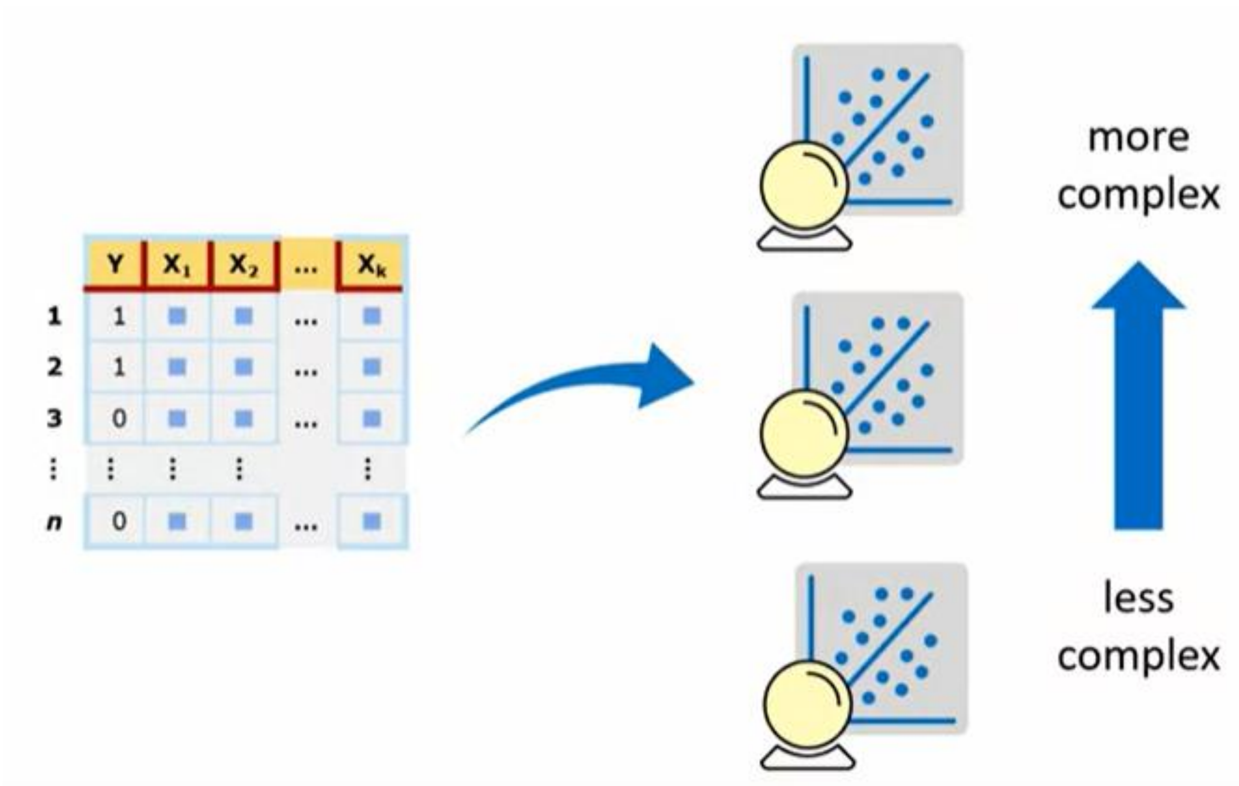
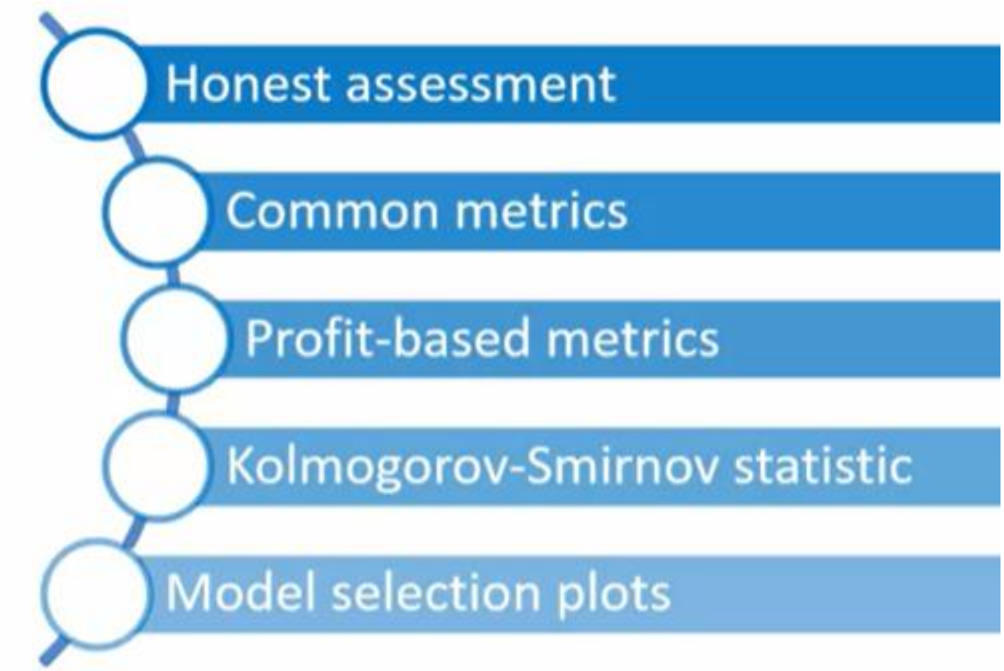
SBA Statistical Business Analyst using SAS

SBA3 Predictive Modeling with Logistic Regression

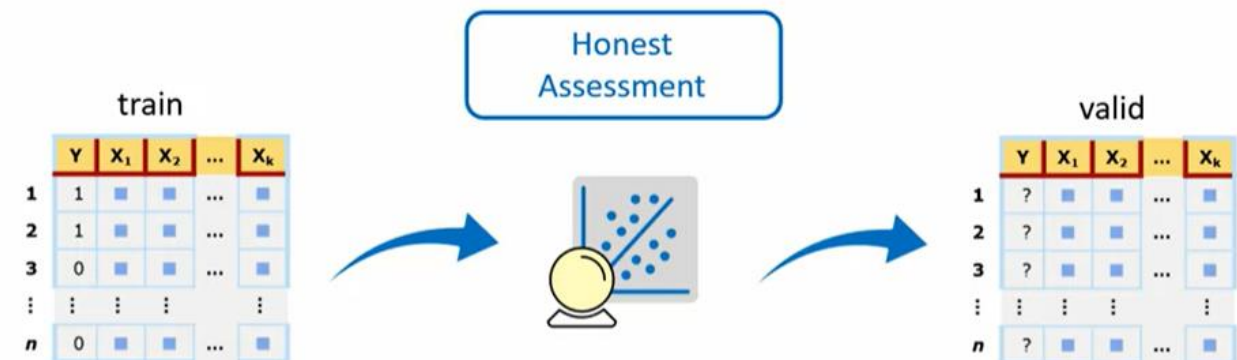
W5A Honest Assessment of the Model

Overview





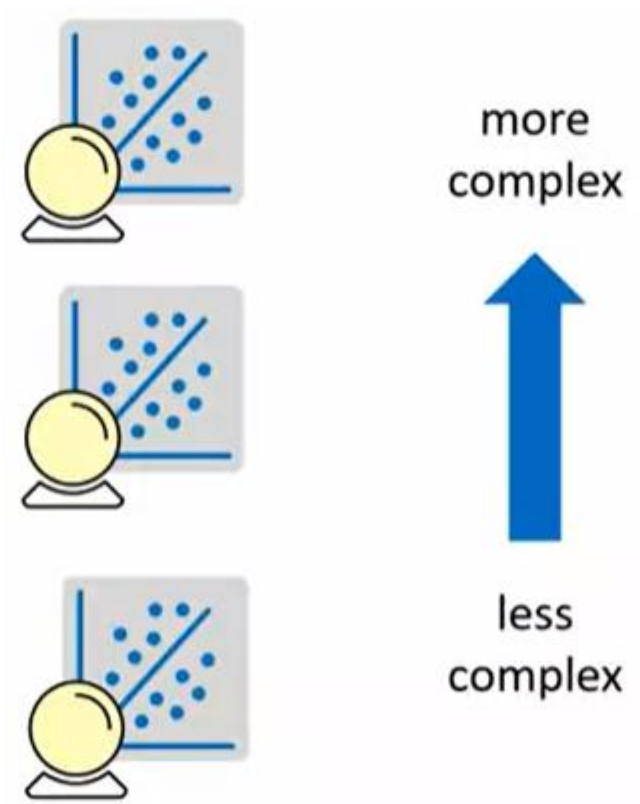
Introduction

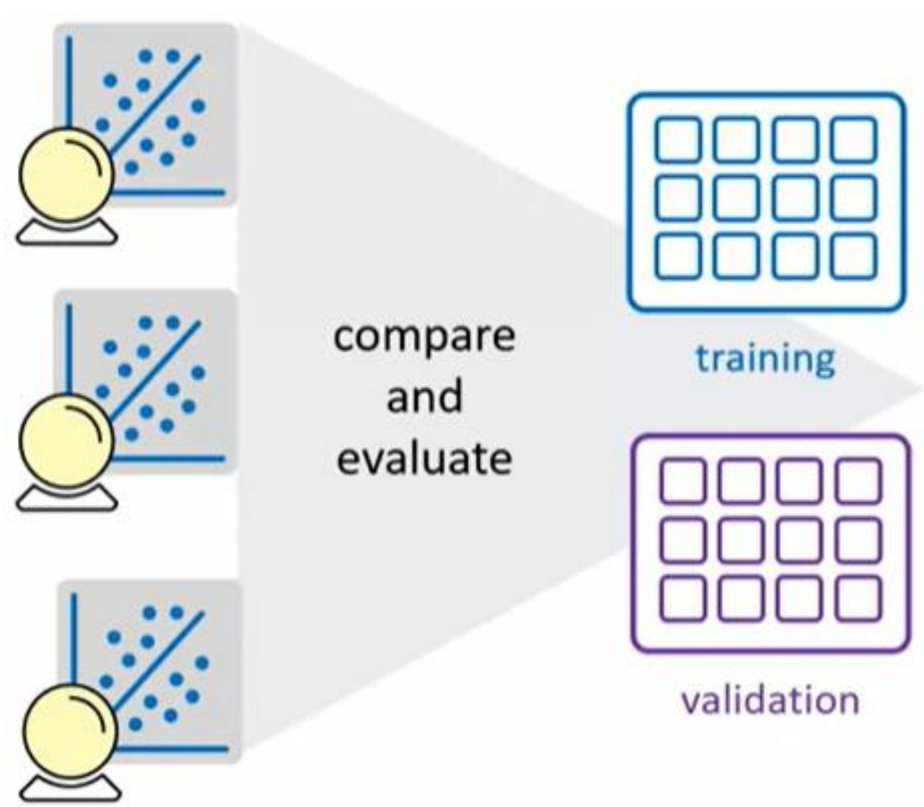


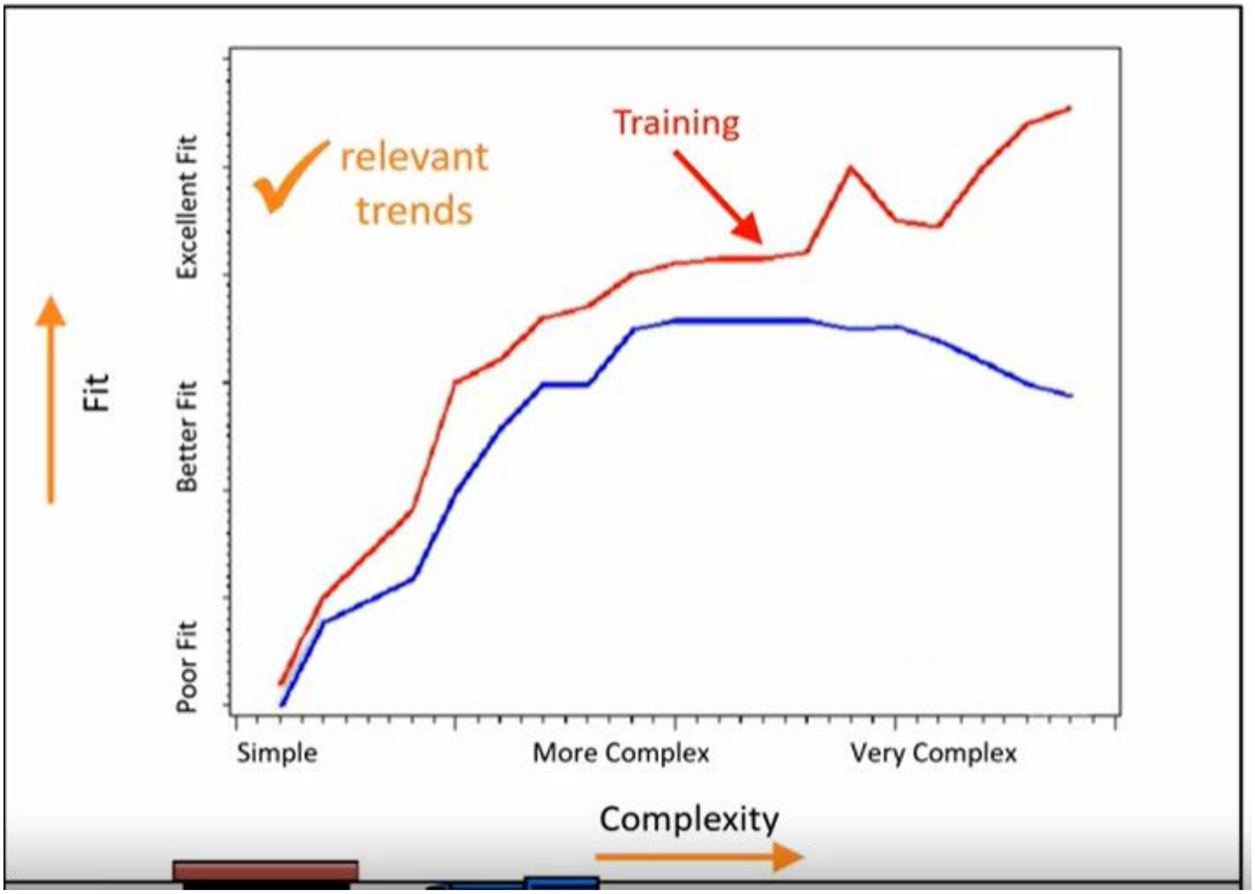
In this topic, you learn to do the following:

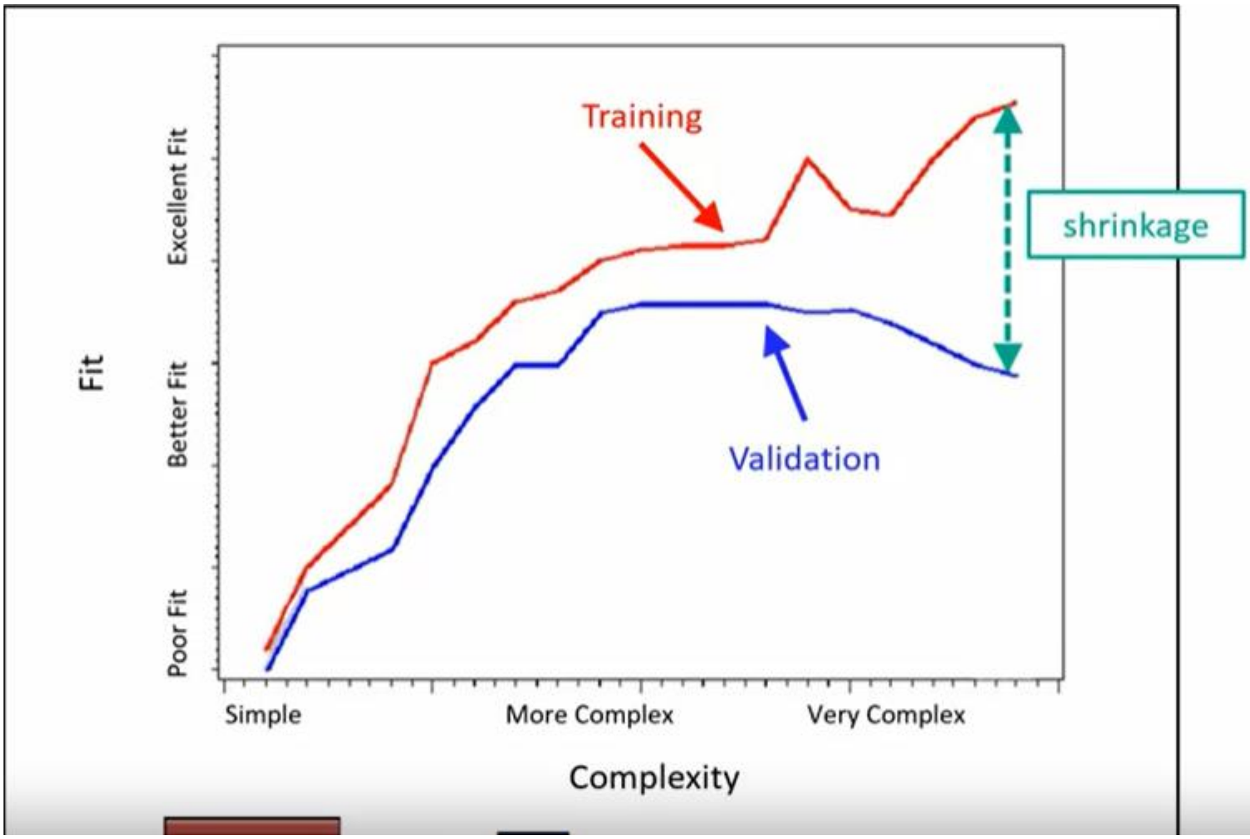
- explain the benefit of comparing the training and validation data fit statistics versus model complexity
- prepare the input variables in the validation data set

Fit versus Complexity





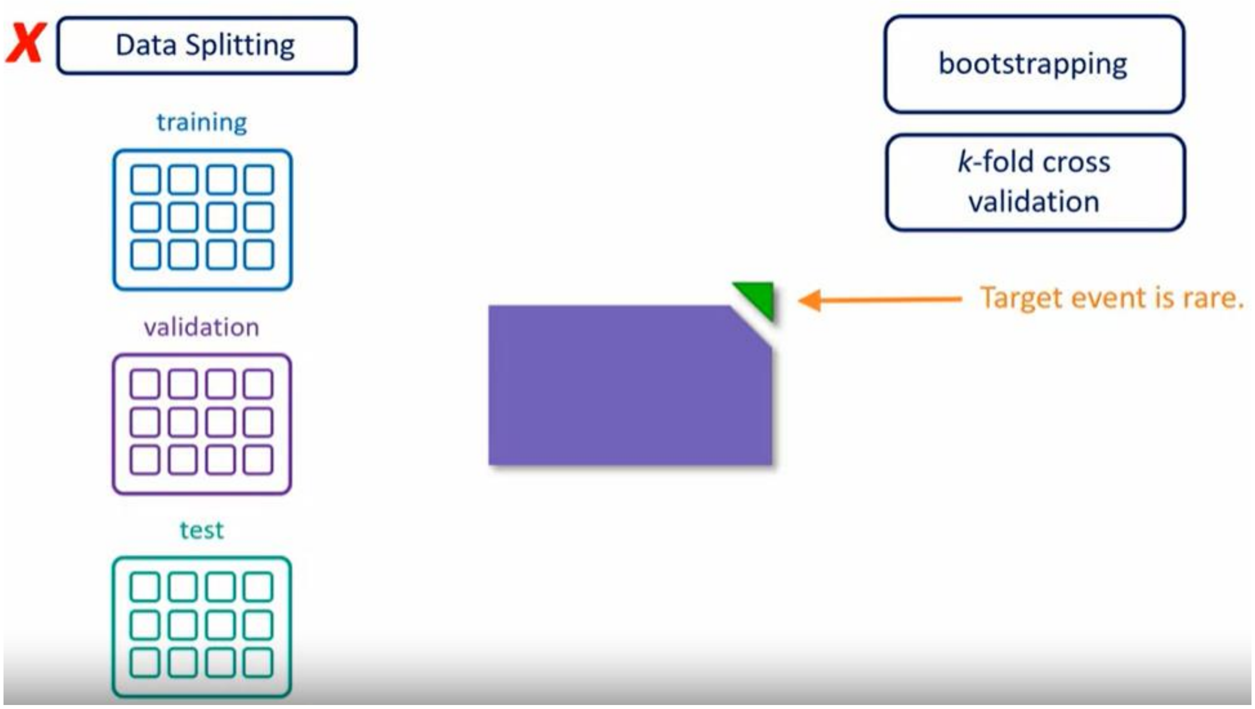

Training
relevant
trends
Excellent Fit
Better Fit
Poor Fit
Fit
Simple
More Complex
Very Complex
Complexity

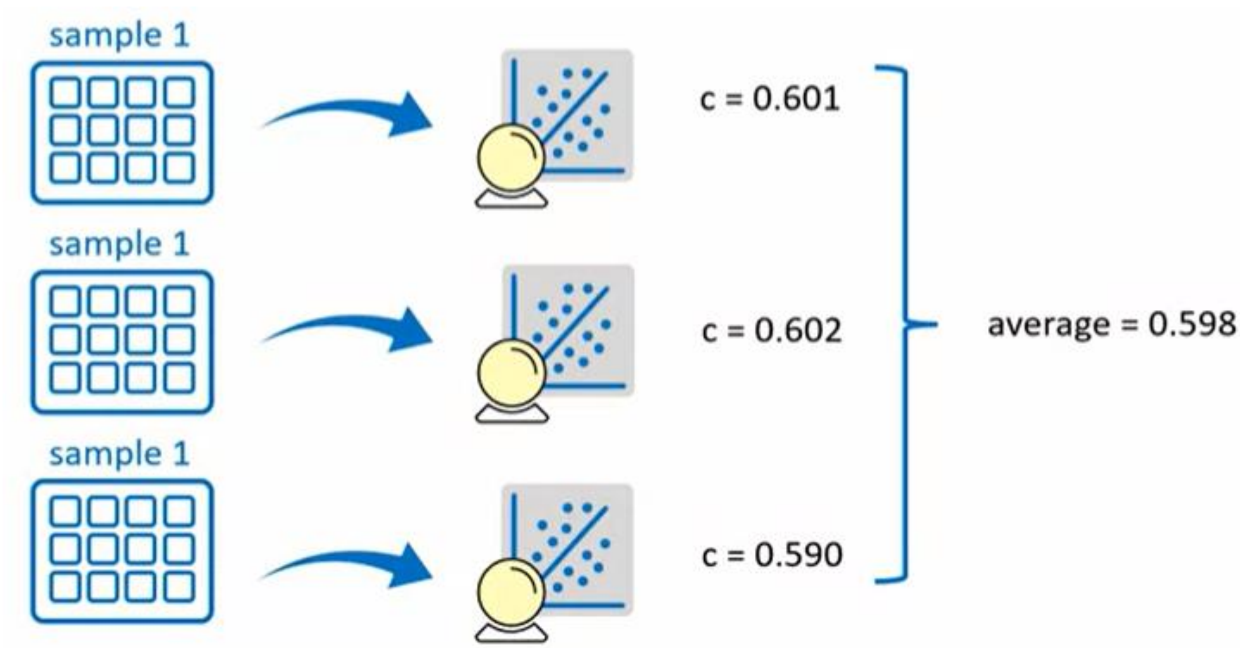


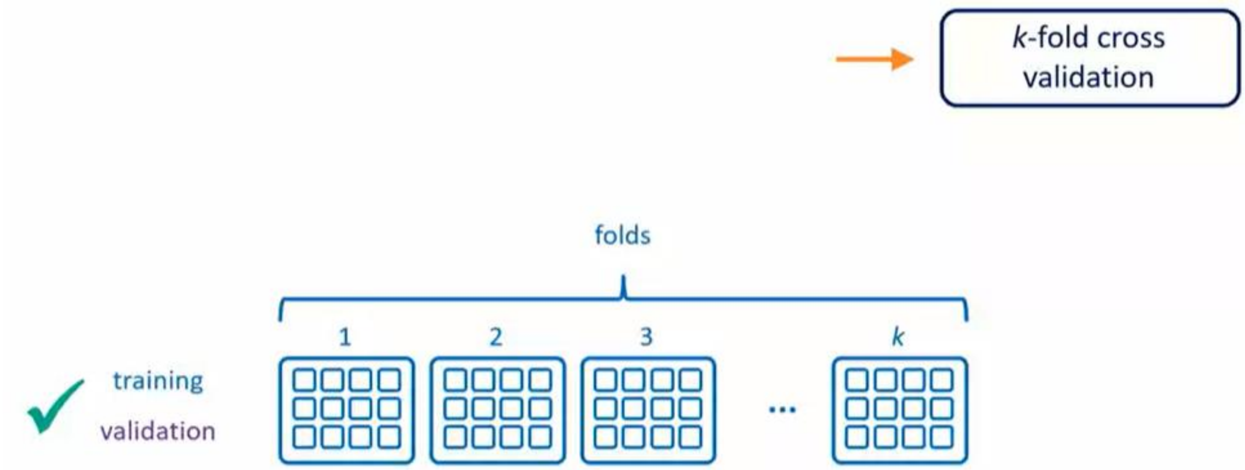
Example Rule:

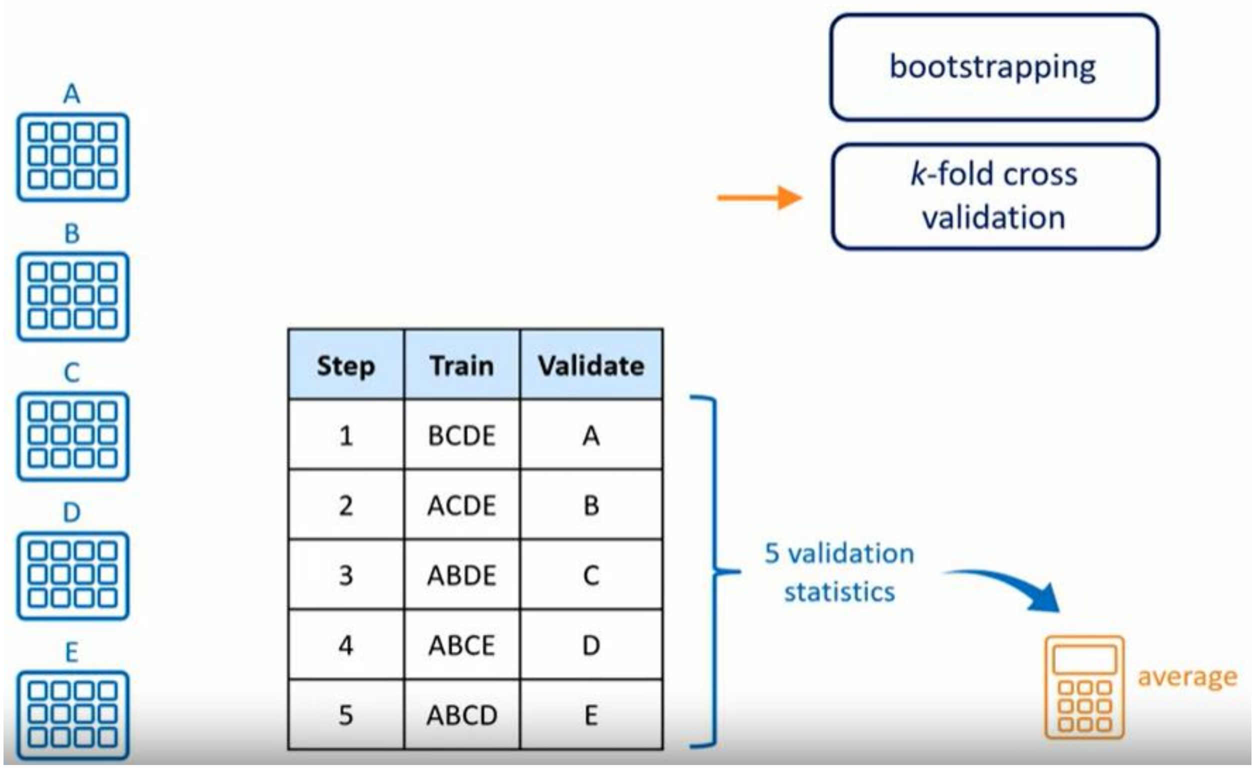
- simplest model
- highest validation fit measure
- $\leq$ 10% shrinkage

Assessing Models when Target Even Data is Rare

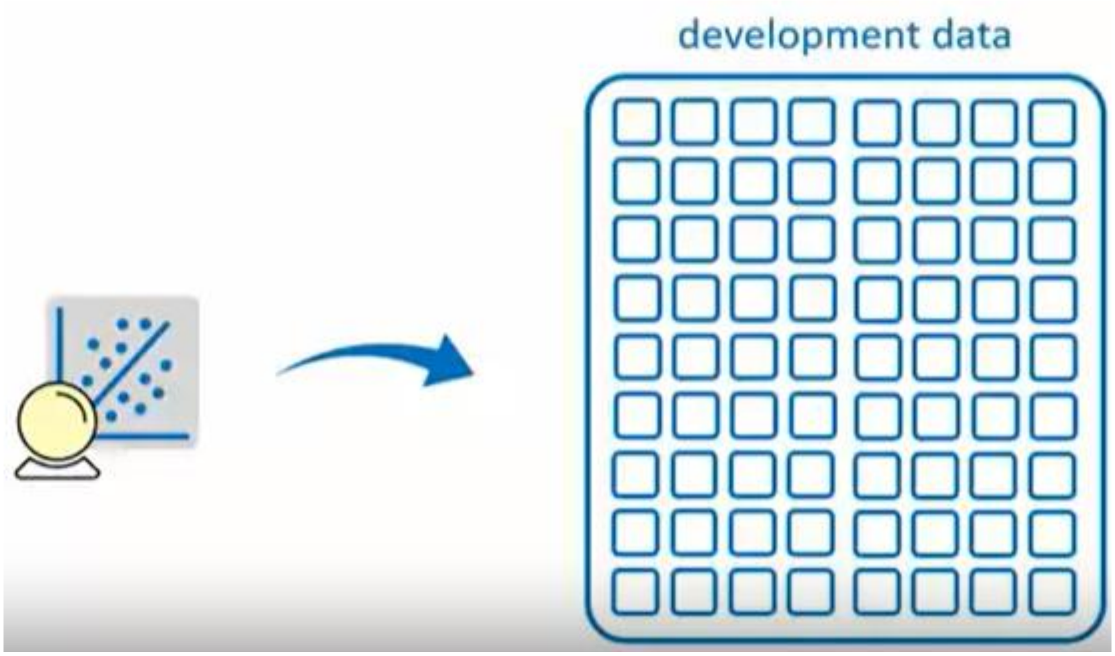








Step	Train	Validate
1	BCDE	A
2	ACDE	B
3	ABDE	C
4	ABCE	D
5	ABCD	E



Demo Preparing the Validation Data

pmlr01d02.sas

```
data work.train(drop=selected SelectionProb SamplingWeight)
     work.valid(drop=selected SelectionProb SamplingWeight);
   set work.develop_sample;
   if selected then output work.train;
   else output work.valid;
run;
```

* Identify inputs that need imputation using PROC MEANS.

* Create an output data set with the medians of the inputs that have missing values using PROC UNIVARIATE.

* Impute values, create inputs, and apply a transformation using the DATA step.

pmlr04d01.sas

```
title1 "Variables with Missing Values on the Validation Data Set";
proc means data=work.valid nmiss;
   var SavBal DDA CD Sav MM IRA IRABal ATMAmt ILS NSF SDB CCBal Inv
       DepAmt Dep ATM CC;
run;
```

Variables with Missing Values on the Validation Data Set

The MEANS Procedure

Variable	Label	N Miss
SavBal	Saving Balance	0
DDA	Checking Account	0
CD	Certificate of Deposit	0
Sav	Saving Account	0
MM	Money Market	0
IRA	Retirement Account	0
IRABal	IRA Balance	0
ATMAmt	ATM Withdrawal Amount	0
ILS	Installment Loan	0
NSF	Number Insufficient Fund	0
SDB	Safety Deposit Box	0
CCBal	Credit Card Balance	1350
Inv	Investment	1350
DepAmt	Amount Deposited	0
Dep	Checking Deposits	0
ATM	ATM	0
CC	Credit Card	1350

```
proc univariate data=work.train_imputed_swoe_bins noprint;
   var cc ccbal inv;
   output out=work.medians
          pctlpts=50
          pctlpre=cc ccbal inv;
run;
```

```
data work.valid_imputed_swoe_bins(drop=cc50 ccbal50 inv50 i);
   if _N_=1 then set work.medians;
   set work.valid;
   array x(*) cc ccbal inv;
   array med(*) cc50 ccbal50 inv50;
   do i=1 to dim(x);
      if x(i)=. then x(i)=med(i);
   end;
   %include brswoe;
   if not dda then ddabal=&mean;
   %include rank;
run;
```

PROC STDIZE

/* Code for the Lesson 1, 2 and 3 Demonstrations in the SAS e-Course

"Predictive Modeling Using Logistic Regression" */

/* The demonstrations in this SAS e-course build on each other. This file contains the code for all demonstrations in Lesson 1, 2 and 3.

If you started a new SAS session since you ran the previous demonstration(s), you need to set up access to the course files (see the Course Overview and Data Setup) and then and re-run the code for all previous demonstrations. The title of each demonstration and the corresponding program file name appear in a comment above the code for that demo.

Before you submit the code, make any necessary modifications to the code, if indicated in comments.

Note: Most of the code requires no modifications.

Submit the code and check the log to verify that it ran without errors.

After performing the steps above, you are ready to proceed with the current demonstration!

```
*/

/* ===================================================== */
/* Lesson 1, Section 1: l1d1.sas
  Demonstration: Examining the Code for Generating
  Descriptive Statistics and Frequency Tables
  [m641_1_i; derived from pmlr01d01.sas]            */
/* ===================================================== */

data work.develop;
  set pmlr.develop;
run;

%global inputs;
%let inputs=ACCTAGE DDA DDABAL DEP DEPAMT CASHBK
        CHECKS DIRDEP NSF NSFAMT PHONE TELLER
        SAV SAVBAL ATM ATMAMT POS POSAMT CD
        CDBAL IRA IRABAL LOC LOCBAL INV
        INVBAL ILS ILSBAL MM MMBAL MMCRED MTG
        MTGBAL CC CCBAL CCPURC SDB INCOME
        HMOWN LORES HMVAL AGE CRSCORE MOVED
        INAREA;

proc means data=work.develop n nmiss mean min max;
  var &inputs;
run;
```

```
proc freq data=work.develop;
  tables ins branch res;
run;

/* ===================================================== */
/* Lesson 1, Section 2: l1d2.sas
  Demonstration: Splitting the Data
  [m641_2_h; derived from pmlr01d02.sas]          */
/* ===================================================== */


/* Sort the data by the target in preparation for stratified sampling. */

proc sort data=work.develop out=work.develop_sort;
  by ins;
run;

/* The SURVEYSELECT procedure will perform stratified sampling
  on any variable in the STRATA statement. The OUTALL option
  specifies that you want a flag appended to the file to
  indicate selected records, not simply a file comprised
  of the selected records. */

proc surveyselect noprint data=work.develop_sort
            samprate=.6667 stratumseed=restore
            out=work.develop_sample
            seed=44444 outall;
  strata ins;
run;
```

```
/* Verify stratification. */

proc freq data=work.develop_sample;
  tables ins*selected;
run;

/* Create training and validation data sets. */

data work.train(drop=selected SelectionProb SamplingWeight)
    work.valid(drop=selected SelectionProb SamplingWeight);
  set work.develop_sample;
  if selected then output work.train;
  else output work.valid;
run;




/* ====================================================== */
/* Lesson 2, Section 1: l2d1.sas
  Demonstration: Fitting a Basic Logistic Regression Model,
  Parts 1 and 2
  [m642_1_k1, m642_1_k2; derived from pmlr02d01.sas]    */
/* ====================================================== */

title1 "Logistic Regression Model for the Variable Annuity Data Set";
proc logistic data=work.train
         plots(only maxpoints=none)=(effect(clband x=(ddabal depamt checks res))
         oddsratio (type=horizontalstat));
```

```
  class res (param=ref ref='S') dda (param=ref ref='0');
  model ins(event='1')=dda ddabal dep depamt
           cashbk checks res / stb clodds=pl;
  units ddabal=1000 depamt=1000 / default=1;
  oddsratio 'Comparisons of Residential Classification' res / diff=all cl=pl;
  effectplot slicefit(sliceby=dda x=ddabal) / noobs;
  effectplot slicefit(sliceby=dda x=depamt) / noobs;
run;
title1;



/* ===================================================== */
/* Lesson 2, Section 1: l2d2.sas
  Demonstration: Scoring New Cases
  [m642_1_n; derived from pmlr02d02.sas]             */
/* ===================================================== */

/* Score a new data set with one run of the LOGISTIC procedure with the
  SCORE statement.  */

proc logistic data=work.train noprint;
  class res (param=ref ref='S');
  model ins(event='1')= res dda ddabal dep depamt cashbk checks;
  score data = pmlr.new out=work.scored1;
run;

title1 "Predicted Probabilities from Scored Data Set";
proc print data=work.scored1(obs=10);
  var p_1 dda ddabal dep depamt cashbk checks res;
```

```
run;

title1 "Mean of Predicted Probabilities from Scored Data Set";
proc means data=work.scored1 mean nolabels;
  var p_1;
run;

/* Score a new data set with the OUTMODEL= amd INMODEL= options */

proc logistic data=work.train outmodel=work.scoredata noprint;
  class res (param=ref ref='S');
  model ins(event='1')= res dda ddabal dep depamt cashbk checks;
run;

proc logistic inmodel=work.scoredata noprint;
  score data = pmlr.new out=work.scored2;
run;

title1 "Predicted Probabilities from Scored Data Set";
proc print data=work.scored2(obs=10);
  var p_1 dda ddabal dep depamt cashbk checks res;
run;

/* Score a new data set with the CODE Statement  */

proc logistic data=work.train noprint;
  class res (param=ref ref='S');
  model ins(event='1')= res dda ddabal dep depamt cashbk checks;
  code file="&PMLRfolder/pmlr_score.txt";
```

```
run;

data work.scored3;
  set pmlr.new;
  %include "&PMLRfolder/pmlr_score.txt";
run;

title1 "Predicted Probabilities from Scored Data Set";
proc print data=work.scored3(obs=10);
  var p_ins1 dda ddabal dep depamt cashbk checks res;
run;
title1 ;


/* ===================================================== */
/* Lesson 2, Section 2: l2d3.sas
  Demonstration: Correcting for Oversampling
  [m642_2_f; derived from pmlr02d03.sas]            */
/* ===================================================== */

/* Specify the prior probability to correct for oversampling.  */
%global pi1;
%let pi1=.02;

/* Correct predicted probabilities */

proc logistic data=work.train noprint;
  class res (param=ref ref='S');
  model ins(event='1')=dda ddabal dep depamt cashbk checks res;
```

```
  score data=pmlr.new out=work.scored4 priorevent=&pi1;
run;

title1 "Adjusted Predicted Probabilities from Scored Data Set";
proc print data=work.scored4(obs=10);
  var p_1 dda ddabal dep depamt cashbk checks res;
run;

title1 "Mean of Adjusted Predicted Probabilities from Scored Data Set";
proc means data=work.scored4 mean nolabels;
  var p_1;
run;
title1 ;

/* Correct probabilities in the Score Code */

proc logistic data=work.train noprint;
  class res (param=ref ref='S');
  model ins(event='1')=dda ddabal dep depamt cashbk checks res;
  /* File suffix "txt" is used so you can view the file */
  /* with a native text editor. SAS prefers "sas", but  */
  /* when specified as a filename, SAS does not care.   */
  code file="&PMLRfolder/pmlr_score_adj.txt";
run;

%global rho1;
proc SQL noprint;
  select mean(INS) into :rho1
  from work.train;
```

```
quit;

data new;
  set pmlr.new;
  off=log(((1-&pi1)*&rho1)/(&pi1*(1-&rho1)));
run;

data work.scored5;
  set work.new;
  %include "&PMLRfolder/pmlr_score_adj.txt";
  eta=log(p_ins1/p_ins0) - off;
  prob=1/(1+exp(-eta));
run;

title1 "Adjusted Predicted Probabilities from Scored Data Set";
proc print data=scored5(obs=10);
  var prob dda ddabal dep depamt cashbk checks res;
run;
title1 ;



/* ===================================================== */
/* Lesson 3, Section 1: l3d1.sas
  Demonstration: Imputing Missing Values
  [m643_1_h; derived from pmlr03d01.sas]              */
/* ===================================================== */

title1 "Variables with Missing Values";
```

```
proc print data=work.train(obs=15);
  var ccbal ccpurc income hmown;
run;
title1 ;

/* Create missing indicators */
data work.train_mi(drop=i);
  set work.train;
  /* name the missing indicator variables */
  array mi{*} MIAcctAg MIPhone MIPOS MIPOSAmt
          MIInv MIInvBal MICC MICCBal
          MICCPurc MIIncome MIHMOwn MILORes
          MIHMVal MIAge MICRScor;
  /* select variables with missing values */
  array x{*} acctage phone pos posamt
          inv invbal cc ccbal
          ccpurc income hmown lores
          hmval age crscore;
  do i=1 to dim(mi);
    mi{i}=(x{i}=.);
    nummiss+mi{i};
  end;
run;

/* Impute missing values with the median */
proc stdize data=work.train_mi reponly method=median out=work.train_imputed;
  var &inputs;
run;
```

```
title1 "Imputed Values with Missing Indicators";
proc print data=work.train_imputed(obs=12);
  var ccbal miccbal ccpurc miccpurc income miincome hmown mihmown nummiss;
run;
title1 ;



/* ====================================================== */
/* Lesson 3, Section 2: l3d2a.sas
  Demonstration: Collapsing the Levels of a Nominal Input,
  Part 1
  [m643_2_g1; derived from pmlr03d02.sas]              */
/* ====================================================== */

proc means data=work.train_imputed noprint nway;
  class branch;
  var ins;
  output out=work.level mean=prop;
run;

title1 "Proportion of Events by Level";
proc print data=work.level;
run;

/* Use ODS to output the ClusterHistory output object into a data set
  named "cluster." */

ods output clusterhistory=work.cluster;
```

```
proc cluster data=work.level method=ward outtree=work.fortree
     plots=(dendrogram(vertical height=rsq));
  freq _freq_;
  var prop;
  id branch;
run;


/* ====================================================== */
/* Lesson 3, Section 2: l3d2b.sas
  Demonstration: Collapsing the Levels of a Nominal Input,
  Part 2
  [m643_2_g2; derived from pmlr03d02.sas]           */
/* ====================================================== */

/* Use the FREQ procedure to get the Pearson Chi^2 statistic of the
  full BRANCH*INS table. */

proc freq data=work.train_imputed noprint;
  tables branch*ins / chisq;
  output out=work.chi(keep=_pchi_) chisq;
run;

/* Use a one-to-many merge to put the Chi^2 statistic onto the clustering
  results. Calculate a (log) p-value for each level of clustering. */

data work.cutoff;
  if _n_=1 then set work.chi;
  set work.cluster;
```

```
  chisquare=_pchi_*rsquared;
  degfree=numberofclusters-1;
  logpvalue=logsdf('CHISQ',chisquare,degfree);
run;

/* Plot the log p-values against number of clusters. */

title1 "Plot of the Log of the P-Value by Number of Clusters";
proc sgplot data=work.cutoff;
  scatter y=logpvalue x=numberofclusters
        / markerattrs=(color=blue symbol=circlefilled);
  xaxis label="Number of Clusters";
  yaxis label="Log of P-Value" min=-120 max=-85;
run;
title1 ;

/* Create a macro variable (&ncl) that contains the number of clusters
  associated with the minimum log p-value. */

proc sql;
  select NumberOfClusters into :ncl
  from work.cutoff
  having logpvalue=min(logpvalue);
quit;

proc tree data=work.fortree nclusters=&ncl out=work.clus noprint;
  id branch;
run;
```

```
proc sort data=work.clus;
  by clusname;
run;

title1 "Levels of Branch by Cluster";
proc print data=work.clus;
  by clusname;
  id clusname;
run;
title1 ;

/* The DATA Step creates the scoring code to assign the branches to a cluster. */

filename brclus "&PMLRfolder/branch_clus.sas";

data _null_;
  file brclus;
  set work.clus end=last;
  if _n_=1 then put "select (branch);";
  put "  when ('" branch +(-1) "') branch_clus = '" cluster +(-1) "';";
  if last then do;
    put "  otherwise branch_clus = 'U';" / "end;";
  end;
run;

data work.train_imputed_greenacre;
  set work.train_imputed;
  %include brclus / source2;
run;
```

```
/* ===================================================== */
/* Lesson 3, Section 2: l3d3.sas
   Demonstration: Computing the Smoothed Weight of Evidence
   [m643_2_j; derived from pmlr03d03.sas]             */
/* ===================================================== */

/* Rho1 is the proportion of events in the training data set. */
%global rho1;
proc sql noprint;
   select mean(ins) into :rho1
   from work.train_imputed;
run;

/* The output data set from PROC MEANS will have the number of
   observations and events for each level of branch. */

proc means data=work.train_imputed sum nway noprint;
   class branch;
   var ins;
   output out=work.counts sum=events;
run;

/* The DATA Step creates the scoring code that assigns each branch to
   a value of the smoothed weight of evidence. */


filename brswoe "&PMLRfolder/swoe_branch.sas";
```

```
data _null_;
  file brswoe;
  set work.counts end=last;
  logit=log((events + &rho1*24)/(_FREQ_ - events + (1-&rho1)*24));
  if _n_=1 then put "select (branch);" ;
  put "  when ('" branch +(-1) "') branch_swoe = " logit ";" ;
  if last then do;
  logit=log(&rho1/(1-&rho1));
  put "  otherwise branch_swoe = " logit ";" / "end;";
  end;
run;

data work.train_imputed_swoe;
  set work.train_imputed;
  %include brswoe / source2;
run;


/* ===================================================== */
/* Lesson 3, Section 3: l3d4.sas
  Demonstration: Reducing Redundancy by Clustering Variables
  [m643_3_i; derived from pmlr03d04.sas]             */
/* ===================================================== */

/* Use the ODS OUTPUT statement to generate data sets based on the variable
  clustering results and the clustering summary. */

ods select none;
```

```
ods output clusterquality=work.summary
        rsquare=work.clusters;

proc varclus data=work.train_imputed_swoe maxeigen=.7 hi;
  var &inputs branch_swoe miacctag
     miphone mipos miposamt miinv
     miinvbal micc miccbal miccpurc
     miincome mihmown milores mihmval
     miage micrscor;
run;
ods select all;

/* Use the CALL SYMPUT function to create a macro variable:&NVAR =
  the number of of clusters. This is also the number of variables
  in the analysis, going forward. */

%global nvar;
data _null_;
  set work.summary;
  call symput('nvar',compress(NumberOfClusters));
run;

title1 "Variables by Cluster";
proc print data=work.clusters noobs label split='*';
  where NumberOfClusters=&nvar;
  var Cluster Variable RSquareRatio VariableLabel;
  label RSquareRatio="1 - RSquare*Ratio";
run;
title1 ;
```

```
title1 "Variation Explained by Clusters";
proc print data=work.summary label;
run;

/* Choose a representative from each cluster.  */
%global reduced;
%let reduced=branch_swoe MIINCOME Dep CCBal MM Income ILS POS NSF CD
        DDA LOC Age Inv InArea AcctAge Moved CRScore MICRScor
        IRABal MIAcctAg SavBal CashBk DDABal SDB InvBal CCPurc
        ATMAmt Sav CC Phone HMOwn DepAmt IRA MTG ATM LORes;


/* ===================================================== */
/* Lesson 3, Section 4:  l3d5a.sas
  Demonstration: Performing Variable Screening, Part 1
  [m643_4_e1; derived from pmlr03d05.sas]          */
/* ===================================================== */

ods select none;
ods output spearmancorr=work.spearman
       hoeffdingcorr=work.hoeffding;

proc corr data=work.train_imputed_swoe spearman hoeffding;
  var ins;
  with &reduced;
run;

ods select all;
```

```
proc sort data=work.spearman;
   by variable;
run;

proc sort data=work.hoeffding;
   by variable;
run;

data work.correlations;
  merge work.spearman(rename=(ins=scorr pins=spvalue))
       work.hoeffding(rename=(ins=hcorr pins=hpvalue));
  by variable;
  scorr_abs=abs(scorr);
  hcorr_abs=abs(hcorr);
run;

proc rank data=work.correlations out=work.correlations1 descending;
   var scorr_abs hcorr_abs;
   ranks ranksp rankho;
run;

proc sort data=work.correlations1;
  by ranksp;
run;

title1 "Rank of Spearman Correlations and Hoeffding Correlations";
proc print data=work.correlations1 label split='*';
  var variable ranksp rankho scorr spvalue hcorr hpvalue;
```

```
  label ranksp ='Spearman rank*of variables'
        scorr  ='Spearman Correlation'
        spvalue='Spearman p-value'
        rankho ='Hoeffding rank*of variables'
        hcorr  ='Hoeffding Correlation'
        hpvalue='Hoeffding p-value';
run;



/* ===================================================== */
/* Lesson 3, Section 4: l3d5b.sas
  Demonstration: Performing Variable Screening, Part 2
  [m643_4_e2; derived from pmlr03d05.sas]            */
/* ===================================================== */

/* Find values for reference lines */
%global vref href;
proc sql noprint;
  select min(ranksp) into :vref
  from (select ranksp
  from work.correlations1
  having spvalue > .5);

  select min(rankho) into :href
  from (select rankho
  from work.correlations1
  having hpvalue > .5);
quit;
```

```
/* Plot variable names, Hoeffding ranks, and Spearman ranks. */

title1 "Scatter Plot of the Ranks of Spearman vs. Hoeffding";
proc sgplot data=work.correlations1;
  refline &vref / axis=y;
  refline &href / axis=x;
  scatter y=ranksp x=rankho / datalabel=variable;
  yaxis label="Rank of Spearman";
  xaxis label="Rank of Hoeffding";
run;
title1 ;

%global screened;
%let screened=SavBal Dep DDA CD Sav CC ATM MM branch_swoe Phone IRA IRABal
          DDABal ATMAmt ILS POS NSF CCPurc SDB DepAmt CCBal Inv InArea
          Age CashBk MICRScor Income;


/* ===================================================== */
/* Lesson 3, Section 4: l3d6.sas
  Demonstration: Creating Empirical Logit Plots
  [m643_4_i; derived from pmlr03d06.sas]            */
/* ===================================================== */

%global var;
%let var=DDABal;

/* Group the data by the variable of interest in order to create
  empirical logit plots.   */
```

```
proc rank data=work.train_imputed_swoe groups=100 out=work.ranks;
  var &var;
  ranks bin;
run;

title1 "Checking Account Balance by Bin";
proc print data=work.ranks(obs=10);
  var &var bin;
run;

/* The data set BINS will contain:INS=the count of successes in each bin,
  _FREQ_=the count of trials in each bin, DDABAL=the avg DDABAL in each bin. */

proc means data=work.ranks noprint nway;
  class bin;
  var ins &var;
  output out=work.bins sum(ins)=ins mean(&var)=&var;
run;

title1 "Number of Observations, Events, and Average Checking Account Balance by Bin";
proc print data=work.bins(obs=10);
run;

/* Calculate the empirical logit */

data work.bins;
  set work.bins;
  elogit=log((ins+(sqrt(_FREQ_ )/2))/
```

```
        ( _FREQ_ -ins+(sqrt(_FREQ_ )/2)));
run;

title1 "Empirical Logit against &var";
proc sgplot data=work.bins;
  reg y=elogit x=&var /
      curvelabel="Linear Relationship?"
      curvelabelloc=outside
      lineattrs=(color=ligr);
  series y=elogit x=&var;
run;

title1 "Empirical Logit against Binned &var";
proc sgplot data=work.bins;
  reg y=elogit x=bin /
      curvelabel="Linear Relationship?"
      curvelabelloc=outside
      lineattrs=(color=ligr);
  series y=elogit x=bin;
run;



/* ===================================================== */
/* Lesson 3, Section 4: l3d7a.sas
  Demonstration: Accommodating a Nonlinear Relationship,
  Part 1
  [m643_4_m1; derived from pmlr03d07.sas]            */
/* ===================================================== */
```

```
title1 "Checking Account Balance and INS by Checking Account";
proc means data=work.train_imputed_swoe mean median min max;
  class dda;
  var ddabal ins;
run;

/* A possible remedy for that non-linearity is to replace the logical
  imputation of 0 for non-DDA customers with the mean. */

%global mean;
proc sql noprint;
  select mean(ddabal) into :mean
  from work.train_imputed_swoe where dda;
quit;

data work.train_imputed_swoe_dda;
  set work.train_imputed_swoe;
  if not dda then ddabal=&mean;
run;

/* Create new logit plots */
%global var;
%let var=DDABal;

proc rank data=work.train_imputed_swoe_dda groups=100 out=work.ranks;
  var &var;
  ranks bin;
run;
```

```
proc means data=work.ranks noprint nway;
  class bin;
  var ins &var;
  output out=work.bins sum(ins)=ins mean(&var)=&var;
run;

/* Calculate the empirical logit */
data work.bins;
  set work.bins;
  elogit=log((ins+(sqrt(_FREQ_ )/2))/
       ( _FREQ_ -ins+(sqrt(_FREQ_ )/2)));
run;

title1 "Empirical Logit against &var";
proc sgplot data=work.bins;
  reg y=elogit x=&var /
     curvelabel="Linear Relationship?"
    curvelabelloc=outside
    lineattrs=(color=ligr);
  series y=elogit x=&var;
run;

title1 "Empirical Logit against Binned &var";
proc sgplot data=work.bins;
  reg y=elogit x=bin /
     curvelabel="Linear Relationship?"
     curvelabelloc=outside
     lineattrs=(color=ligr);
  series y=elogit x=bin;
```

```
run;


/* ====================================================== */
/* Lesson 3, Section 4: l3d7b.sas
   Demonstration: Accommodating a Nonlinear Relationship,
   Part 2
   [m643_4_m2; derived from pmlr03d07.sas]            */
/* ====================================================== */

/* Using the binned values of DDABal may make for a more linear
   relationship between the input and the target. The following code
   creates DATA step code to bin DDABal, yielding a new predictor, B_DDABal.  */

/* Rank the observations. */

proc rank data=work.train_imputed_swoe_dda groups=100 out=work.ranks;
   var ddabal;
   ranks bin;
run;

/* Save the endpoints of each bin */

proc means data=work.ranks noprint nway;
   class bin;
   var ddabal;
   output out=endpts max=max;
run;
```

```
title1 "Checking Account Balance Endpoints";
proc print data=work.endpts(obs=10);
run;

/* Write the code to assign individuals to bins according to the DDABal. */

filename rank "&PMLRfolder/rank.sas";

data _null_;
  file rank;
  set work.endpts end=last;
  if _n_=1 then put "select;";
  if not last then do;
    put "  when (ddabal <= " max ") B_DDABal =" bin ";";
  end;
  else if last then do;
    put "  otherwise B_DDABal =" bin ";" / "end;";
  end;
run;

/* Use the code. */

data work.train_imputed_swoe_bins;
  set work.train_imputed_swoe_dda;
  %include rank / source;
run;

title1 "Minimum and Maximum Checking Account Balance by Bin";
proc means data=work.train_imputed_swoe_bins min max;
```

```
  class B_DDABal;
  var DDABal;
run;
title1 ;

/* Switch the binned DDABal (B_DDABal) for the originally scaled
  DDABal input in the list of potential inputs. */
%global screened;
%let screened=SavBal Dep DDA CD Sav CC ATM MM branch_swoe Phone IRA
          IRABal B_DDABal ATMAmt ILS POS NSF CCPurc SDB DepAmt
          CCBal Inv InArea Age CashBk MICRScor Income;



/* ===================================================== */
/* Lesson 3, Section 5: l3d8a.sas
  Demonstration: Detecting Interactions
  [m643_5_m; derived from pmlr03d08.sas]           */
/* ===================================================== */

title1 "P-Value for Entry and Retention";

%global sl;
proc sql;
  select 1-probchi(log(sum(ins ge 0)),1) into :sl
  from work.train_imputed_swoe_bins;
quit;

title1 "Interaction Detection using Forward Selection";
proc logistic data=work.train_imputed_swoe_bins;
```

```
  class res (param=ref ref='S');
  model ins(event='1')= &screened res
            SavBal|Dep|DDA|CD|Sav|CC|ATM|MM|branch_swoe|Phone|IRA|
            IRABal|B_DDABal|ATMAmt|ILS|POS|NSF|CCPurc|SDB|DepAmt|
            CCBal|Inv|InArea|Age|CashBk|MICRScor|Income|res @2 / include=28 clodds=pl
     selection=forward slentry=&sl;
run;



/* ===================================================== */
/* Lesson 3, Section 5: l3d8b.sas
  Demonstration: Using Backward Elimination to Subset the
  Variables
  [m643_5_n; derived from pmlr03d08.sas]            */
/* ===================================================== */

title1 "Backward Selection for Variable Annuity Data Set";
proc logistic data=work.train_imputed_swoe_bins;
  class res (param=ref ref='S');
  model ins(event='1')= &screened res SavBal*B_DDABal MM*B_DDABal
            branch_swoe*ATMAmt B_DDABal*Sav SavBal*SDB
            SavBal*DDA ATMAmt*DepAmt B_DDABal*ATMAmt SavBal*ATMAmt
            SavBal*IRA SavBal*MM SavBal*CC Sav*NSF DDA*ATMAmt Dep*ATM
            IRA*B_DDABal CD*MM MM*IRABal CD*Sav B_DDABal*CashBk Sav*CC
           / clodds=pl
      selection=backward slstay=&sl hier=single fast;
run;
```

```
/* ======================================================= */
/* Lesson 3, Section 5: l3d8c.sas
   Demonstration: Displaying Odds Ratios for Variables
   Involved in Interactions
   [m643_5_o; derived from pmlr03d08.sas]             */
/* ======================================================= */

title1 "Candidate Model for Variable Annuity Data Set";
ods select OddsRatiosPL;
proc logistic data=work.train_imputed_swoe_bins;
   model ins(event='1')= SavBal Dep DDA CD Sav CC ATM MM branch_swoe IRA B_DDABal
                  ATMAmt ILS NSF SDB
                  DepAmt Inv SavBal*B_DDABal MM*B_DDABal
                  branch_swoe*ATMAmt Sav*B_DDABal
                  SavBal*SDB SavBal*DDA AtmAmt*DepAmt B_DDABAL*ATMAmt SavBal*IRA
                  SavBal*MM SavBal*CC Sav*NSF DDA*ATMAmt Dep*ATM IRA*B_DDABal
                  CD*MM CD*Sav Sav*CC / clodds=pl;
   oddsratio B_DDABAL / at(savbal=0, 1211, 52299) cl=pl;
run;



/* ======================================================= */
/* Lesson 3, Section 5: l3d8d.sas
   Demonstration: Creating an Interaction Plot
   [m643_5_r; derived from pmlr03d08.sas]             */
/* ======================================================= */

/*----  MACRO INTERACT  ----*\
Reserved data set names: work.percentiles
```

```
                  work.plot
\*-------------------------*/
%macro interact(data=,target=,event=,inputs=,var1=,var2=,mean_inputs=);

proc logistic data=&data noprint;
  model &target(event="&event")= &inputs;
  code file="&PMLRfolder/interaction.txt";
run;

proc univariate data=&data noprint;
  var &var1 &var2;
  output out=work.percentiles pctlpts=5 25 50 75 95 pctlpre=&var1._p &var2._p;
run;

data _null_;
  set work.percentiles;
  call symput("&var1._p5",&var1._p5);
  call symput("&var1._p25",&var1._p25);
  call symput("&var1._p50",&var1._p50);
  call symput("&var1._p75",&var1._p75);
  call symput("&var1._p95",&var1._p95);
  call symput("&var2._p5",&var2._p5);
  call symput("&var2._p25",&var2._p25);
  call symput("&var2._p50",&var2._p50);
  call symput("&var2._p75",&var2._p75);
  call symput("&var2._p95",&var2._p95);
run;

proc means data=&data noprint;
```

```
  var &mean_inputs;
  output out=work.plot mean=;
run;

data work.plot(drop=_type_ _freq_);
  set work.plot;
  do &var2=&&&var2._p5,&&&var2._p25,&&&var2._p50,&&&var2._p75,&&&var2._p95;
    do &var1=&&&var1._p5,&&&var1._p25,&&&var1._p50,&&&var1._p75,&&&var1._p95;
      %include "&PMLRfolder/interaction.txt";
       output;
    end;
  end;
run;

title1 "Interaction Plot of &var2 by &var1";
proc sgplot data=work.plot;
  series y=p_&target&event x=&var2 / group=&var1;
  yaxis label="Probability of &target";
run;

%mend interact;

%interact(data=train_imputed_swoe_bins,target=ins,event=1,
          inputs=SavBal Dep DDA CD Sav CC ATM MM branch_swoe
          IRA B_DDABal ATMAmt ILS NSF SDB DepAmt Inv
          SavBal*B_DDABal MM*B_DDABal branch_swoe*ATMAmt Sav*B_DDABal
          SavBal*SDB SavBal*DDA AtmAmt*DepAmt B_DDABAL*ATMAmt SavBal*IRA
          SavBal*MM SavBal*CC Sav*NSF DDA*ATMAmt Dep*ATM IRA*B_DDABal
          CD*MM CD*Sav Sav*CC,var1=SavBal,var2=B_DDABal,mean_inputs=SavBal Dep
```

```
        DDA CD Sav CC ATM MM branch_swoe IRA B_DDABal ATMAmt ILS NSF SDB
        DepAmt Inv);


/* ======================================================== */
/* Lesson 3, Section 5: l3d8e.sas
   Demonstration: Using the Best-Subsets Selection Method
   [m643_5_s; derived from pmlr03d08.sas]            */
/* ======================================================== */

data work.train_imputed_swoe_bins;
  set work.train_imputed_swoe_bins;
  resr=(res='R');
  resu=(res='U');
run;

/* Run best subsets */
title1 "Models Selected by Best Subsets Selection";
proc logistic data=work.train_imputed_swoe_bins;
   model ins(event='1')=&screened resr resu SavBal*B_DDABal MM*B_DDABal
         branch_swoe*ATMAmt B_DDABal*Sav SavBal*SDB
         SavBal*DDA ATMAmt*DepAmt B_DDABal*ATMAmt SavBal*ATMAmt
         SavBal*IRA SavBal*MM SavBal*CC Sav*NSF DDA*ATMAmt Dep*ATM
         IRA*B_DDABal CD*MM MM*IRABal CD*Sav B_DDABal*CashBk Sav*CC
         / selection=score best=1;

run;
```

```
/* ====================================================== */
/* Lesson 3, Section 5: l3d8f.sas
   Demonstration: Using Fit Statistics to Select a Model
   [m643_5_L; derived from pmlr03d08.sas]             */
/* ====================================================== */

/* The fitstat macro generates model fit statistics for the
   models selected in the all subsets selection. The macro
   variable IM is set equal to the variable names in the
   model_indx model while the macro variable IC is set
   equal to the number of variables in the model_indx model. */

%macro fitstat(data=,target=,event=,inputs=,best=,priorevent=);

ods select none;
ods output bestsubsets=work.score;

proc logistic data=&data namelen=50;
   model &target(event="&event")=&inputs / selection=score best=&best;
run;

/* The names and number of variables are transferred to macro
   variables using PROC SQL. */

proc sql noprint;
  select variablesinmodel into :inputs1 -
  from work.score;

  select NumberOfVariables into :ic1 -
```

```
 from work.score;
quit;

%let lastindx=&SQLOBS;

%do model_indx=1 %to &lastindx;

%let im=&&inputs&model_indx;
%let ic=&&ic&model_indx;

ods output scorefitstat=work.stat&ic ;
proc logistic data=&data namelen=50;
 model &target(event="&event")=&im;
 score data=&data out=work.scored fitstat
      priorevent=&priorevent;
run;

proc datasets
  library=work
  nodetails
  nolist;
  delete scored;
run;
quit;

%end;

/* The data sets with the model fit statistics are
  concatenated and sorted by BIC. */
```

```
data work.modelfit;
  set work.stat1 - work.stat&lastindx;
  model=_n_;
run;

%mend fitstat;

%fitstat(data=train_imputed_swoe_bins,target=ins,event=1,inputs=&screened resr resu
         SavBal*B_DDABal MM*B_DDABal branch_swoe*ATMAmt B_DDABal*Sav SavBal*SDB
         SavBal*DDA ATMAmt*DepAmt B_DDABal*ATMAmt SavBal*ATMAmt SavBal*IRA
         SavBal*MM SavBal*CC Sav*NSF DDA*ATMAmt Dep*ATM IRA*B_DDABal CD*MM
         MM*IRABal CD*Sav B_DDABal*CashBk Sav*CC,best=1,priorevent=0.02);

proc sort data=work.modelfit;
  by bic;
run;

title1 "Fit Statistics from Models selected from Best-Subsets";
ods select all;
proc print data=work.modelfit;
  var model auc aic bic misclass adjrsquare brierscore;
run;

%global selected;
proc sql;
  select VariablesInModel into :selected
  from work.score
  where numberofvariables=35;
```

```
quit;

/* ====================================================== */
/* Lesson 4, Section 1: l4d1.sas
   Demonstration: Preparing the Validation Data
   [m644_1_g; derived from pmlr04d01.sas]            */
/* ====================================================== */

title1 "Variables with Missing Values on the Validation Data Set";
proc means data=work.valid nmiss;
   var SavBal DDA CD Sav MM IRA IRABal ATMAmt ILS NSF SDB CCBal Inv
       DepAmt Dep ATM CC;
run;

proc univariate data=work.train_imputed_swoe_bins noprint;
   var cc ccbal inv;
   output out=work.medians
          pctlpts=50
          pctlpre=cc ccbal inv;
run;

data work.valid_imputed_swoe_bins(drop=cc50 ccbal50 inv50 i);
   if _N_=1 then set work.medians;
   set work.valid;
   array x(*) cc ccbal inv;
   array med(*) cc50 ccbal50 inv50;
   do i=1 to dim(x);
      if x(i)=. then x(i)=med(i);
   end;
```

```
  %include brswoe;
  if not dda then ddabal=&mean;
  %include rank;
run;
```

Variables with Missing Values on the Validation Data Set

The MEANS Procedure

Variable	Label	N Miss
SavBal	Saving Balance	0
DDA	Checking Account	0
CD	Certificate of Deposit	0
Sav	Saving Account	0
MM	Money Market	0
IRA	Retirement Account	0
IRABal	IRA Balance	0
ATMAmt	ATM Withdrawal Amount	0
ILS	Installment Loan	0
NSF	Number Insufficient Fund	0
SDB	Safety Deposit Box	0
CCBal	Credit Card Balance	1350
Inv	Investment	1350
DepAmt	Amount Deposited	0
Dep	Checking Deposits	0
ATM	ATM	0
CC	Credit Card	1350