SAS® Visual Forecasting 8.1 Time Series Packages

The correct bibliographic citation for this manual is as follows: SAS Institute Inc. 2017. *SAS® Visual Forecasting 8.1: Time Series Packages*. Cary, NC: SAS Institute Inc.

SAS® Visual Forecasting 8.1: Time Series Packages

SAS Institute Inc., SAS Campus Drive, Cary, NC 27513-2414

March 2017

Contents

Chapter 1
Automatic Time Series Analysis and Forecasting Package for the TSMODEL Procedure

Contents

Overview

This document describes the automatic time series analysis and forecasting (ATSM) package. The ATSM package provides objects that are designed to support automatic time series modeling and automatic forecasting. For more information about the statistical methodology that underlies this package, see the relevant chapters—for example, chapters about the HPFDIAGNOSE and HPFENGINE procedures—in *SAS Forecast*

Server Procedures: User's Guide. In addition, a review of the TSMODEL procedure in Chapter 2, "The TSMODEL Procedure" (*SAS Visual Forecasting: Forecasting Procedures*), and the TSM package in Chapter 5, "Time Series Model Package for the TSMODEL Procedure," is also helpful. The ATSM package contains several objects, each of which is designed to carry out a particular task in the time series analysis process. The remainder of this section briefly explains the role of the main ATSM objects.

ATSM Package Summary

- The TSDF object is the time series data frame object.
- The DIAGNOSE object is the time series model generator object.
- The FORENG object is the time series forecasting engine.
- The following time series model specification objects enable you to control different aspects of the model identification process:
  - DIAGSPEC (time series model diagnosis control specification)
  - SELSPEC (custom model selection list specification)
- The following ATSM collector objects enable you to create a snapshot of results from the ATSM objects and save them to CAS tables. Many of these CAS tables contain the same variables as their data set counterparts that are used by the HPFENGINE procedure. In some cases, these tables represent a superset of the columns in the corresponding PROC HPFENGINE data sets.
  - OUTDIAG (persistent diagnostic control specifications)
  - OUTEST (time series model parameter estimates collector)
  - OUTFOR (time series model forecast collector)
  - OUTCOMP (time series model components collector)
  - OUTINDEP (input variables in the model)
  - OUTMODELINFO (time series model information collector)
  - OUTSELECT (time series model selection statistics collector)
  - OUTSTAT (time series model fit statistics collector)
  - OUTFMSG (persistent forecast model selection graph XML)
- The following ATSM repeater objects enable you to restore rows from a CAS table to make them available for use by other ATSM objects. Each repeater object defines a CAS table that is determined by the repeater object's design. Repeater objects perform the inverse function of the collector objects. Not all ATSM collector objects have associated repeater objects. Repeater objects must be bound to an existing CAS table that is compatible with its purpose.
  - INDIAG (replay time series diagnostic control specifications repeater)
  - INFMSG (forecast model selection graph (FMSG) repeater)
  - INEST (automatic time series model parameter estimates repeater)

Figure 1.1 diagrams the relationships between the different objects in the ATSM package.

Figure 1.1 ATSM Data Flow

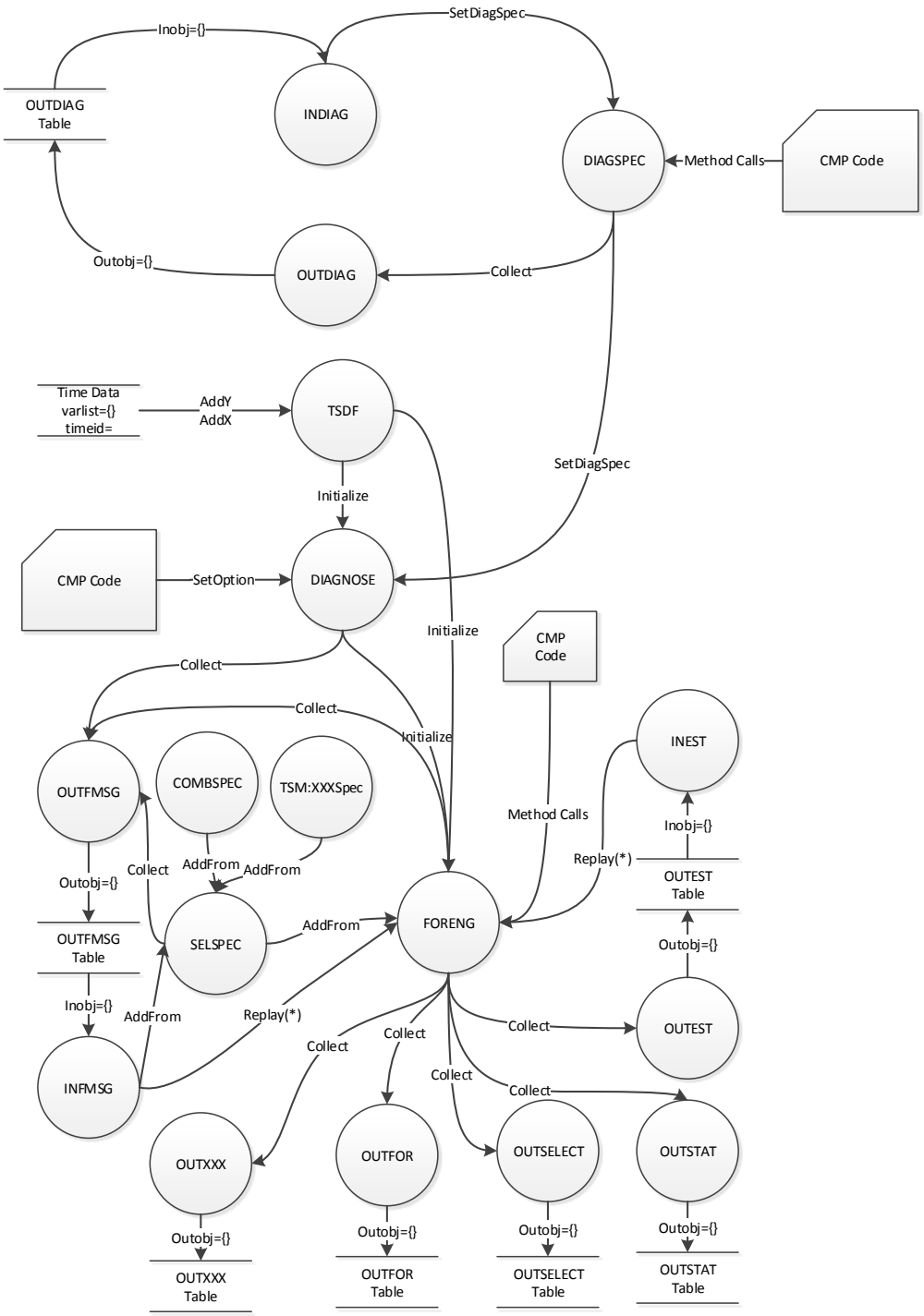


Table 1.1 summarizes the objects in the ATSM package.

Table 1.1 Objects in Automatic Time Series Modeling Package

Object	Description
TSDF	Time series data frame object
DIAGNOSE	Time series model generator object
FORENG	Time series automatic forecasting engine
DIAGSPEC	Time series model diagnosis control specification object
SELSPEC	Model selection list specification object
OUTDIAG	Persistent diagnostic control specifications
OUTEST	Time series model parameter estimates collector object
OUTFOR	Time series model forecast collector object
OUTCOMP	Time series model components collector object
OUTINDEP	Time series model input series collector object
OUTMODELINFO	Time series model information collector object
OUTSELECT	Time series model selection statistics collector object
OUTSTAT	Time series model fit statistics collector object
OUTFMSG	Persistent forecast model selection graph XML
INDIAG	Replay time series diagnostic control specifications
INFMSG	Forecast model selection graph (FMSG) repeater object
INEST	Automatic time series model parameter estimates repeater object

Status Codes

Table 1.2 shows the status return codes (designated by *rc* in method usage statements) that are used in this package. These return codes are numeric values that are returned when a method associated with an object is called. These codes can help determine whether the method executed successfully.

Table 1.2 Status Codes

Status	Meaning
< 0	An unrecoverable error occurred. No result was produced.
= 0	Unconditional success. Requested action completed and normal result produced.
> 0	Conditional success or warning. A result was produced subject to conditions.

TSDF Object Summary

DECLARE OBJECT obj(TSDF) defines an object that is used to group time series variables to be used as input for the other ATSM package objects. As such, TSDF instances are time series data frames. Table 1.3 summarizes the methods that are associated with the TSDF object.

Table 1.3 Methods of the TSDF Object

TSDF Method	Description
Initialize	Initialize TSDF instance
AddY	Add Y series
AddX	Add X series
AddSeries	Add ancillary series
SetOption	Set named option
GetSeries	Get series
NTid	Return the observation count of the time ID variable

TSDF Synopsis

Object declaration statement :

DECLARE OBJECT *obj* (**TSDF**) **;**

Method syntax:

rc = *obj*.**Initialize** ( ) **;**

rc = *obj*.**AddY** (*YSeries[,'Name',Value]*) **;**

rc = *obj*.**AddX** (*XSeries[,'Name',Value]*) **;**

rc = *obj*.**AddSeries** (*Series[,'Name',Value]*) **;**

rc = *obj*.**SetOption** (*'Name',Value [, 'Name',Value])* ;

rc = *obj*.**GetSeries** (*'Name',Result)* ;

Attributes summary:

ntids = *obj*.**ntid** *()* ;

TSDF.Initialize Method

Usage: *rc* = *obj*.**Initialize** *( )* ;

Initialize a TSDF instance to an empty state. This method must be called before setting the time series arrays and other attributes for the TSDF instance.

Parameters

There are no parameters associated with this method.

TSDF.AddY Method

Usage: *rc* = *obj*.**AddY** *(YSeries[,'Name',Value])* ;

Add a dependent time series array (Y) for the TSDF instance. Optional '*Name*', *Value* pairs can be specified in TSDF.AddY.

Parameters

[in] *YSeries* Numeric array used to specify the dependent series for the TSDF instance.

Table 1.4 Allowed Argument for '*Name*', Value Pairs

'*Name*'	*Value*	**Description**
REPMISS	Boolean	See the REPLACEMISSING option in the HPFENGINE procedure.

TSDF.AddX Method

Usage: *rc* = *obj*.**AddX** *(XSeries[,'Name',Value])* ;

Add an independent time series array (X) for the TSDF instance. Each call to the AddX method adds the specified X variable to the TSDF instance. This method can be called as many times as needed to specify all the independent variables that are needed. When this method is used with user-defined models, the name of the *XSeries* variable must match the name of an input symbol (predictor) in the user-defined time series model (see optional '*Name*', *Value* parameters). Only ARIMA and UCM models support predictors.

Parameters

[in] *XSeries* Numeric array used to specify an independent series for the TSDF instance.

Table 1.5 Allowed Arguments for '*Name*', *Value* Pairs

'*Name*'	*Value*	**Description**
EXTEND	String	Specifies an independent series forecast method for extension or replacement
REQUIRED	String	Specifies a variable selection hint for model diagnosis (the default value is 'NO')
KEEP	Boolean	Keeps a variable if it is referenced in a model (the default value is 0)
NODIFF	Boolean	Specifies that the variable does not automatically follow Y differencing (the default value is 0)
CONTROL	Boolean	Specifies that the variable is controllable in forecast functions (the default value is 0)
REPMISS	Boolean	Replaces embedded missing values with forecasts (the default value is 1)
ALIAS	String	Specifies an alias for *XSeries* in lieu of the array name

The EXTEND option controls the generation of future values for the independent variable. The following values are allowed for the EXTEND option:

EXTEND	**Description**
NONE	Uses as specified
AVERAGE	Uses the average of historical values
FIRST	Uses the first nonmissing value
LAST	Uses the last nonmissing value
MIN	Uses the minimum value
MAX	Uses the maximum value
MEDIAN	Uses the median value
STOCHASTIC	Uses the ESMBEST model (default)

The REQUIRED option provides a hint about the importance of the independent variable when the TSDF is used in the DIAGNOSE object. For more information, see the HPFDIAGNOSE procedure documentation. The following values are valid for the REQUIRED option:

REQUIRED	Description
YES	Includes the independent variable unless it causes model fit failure.
MAYBE	Includes the independent variable unless it causes model fit failure and there are no numerical issues in the model fit.
NO	Includes the independent variable if it sufficiently improves the model's information criterion.

- You can use any method for forecasting the independent series and supply all nonmissing values for it. If you supply the nonmissing values, it does not matter how you specify the EXTEND option; the independent series is always used as specified.
- The REPMISS option controls whether embedded missing values in the historical region of the independent series are replaced via the EXTEND method.
- The KEEP option forces the inclusion of the independent variable when it is referenced from a model in the FORENG object during model selection. When KEEP=0, independent variables that might cause a model fit to fail are selectively removed in the FORENG model selection process. When KEEP=1, the independent variable is always kept and a model fit failure excludes the model from consideration during model selection. The KEEP option functions the same as the REQUIRED= option for PROC HPFENGINE.

TSDF.AddSeries Method

Usage: *rc* = *obj*.**AddSeries** *(Series[,'Name',Value])* **;**

Add an ancillary time series array (Series) for the TSDF instance. Ancillary series are used by other computational objects in the program flow. For example, you might include an EXMSPEC in the model selection process for some FORENG object, where the EXMSPEC references specific variables that supply the forecast-related series that are needed by the EXMSPEC object. Optional '*Name*', *Value* pairs can be specified in TSDF.AddSeries.

Parameters

[in] *Series* Numeric array that is used to specify an ancillary series for the TSDF instance.

Table 1.8 Allowed Argument for '*Name*', *Value* Pairs

'*Name*'	*Value*	Description
ALIAS	String	Name of the series in the TSDF (the default is the argument name)

TSDF.GetSeries Method

Usage: *rc* = *obj*.**GetSeries** *('Name',Result)* ;

Retrieve the specified series by its name ('*Name*' or alias) from the TSDF instance into the specified numeric array (*Result*).

Parameters

[in] '*Name*' Character string whose value specifies the variable to return

[out] *Result* Numeric array to receive the variable's series

TSDF Attributes

TSDF.ntid Method

Usage: *ntids* = *obj*.**ntid** *()* ;

Return the length (observation count) of the time ID variable for the TSDF instance. A missing value indicates that the TSDF instance has no time ID variable.

Parameters

There are no parameters associated with this method.

TSDF.SetOption Method

Usage: *rc* = *obj*.**SetOption** *('Name',Value [, 'Name',Value])* ;

Set named option for the TSDF instance. '*Name*' is a character variable. The type of *Value* depends on the value of '*Name*' .

Parameters

[in] '*Name*' Character variable that names the option to set.

[in] *Value* Specifies the value for the named option.

Table 1.9 Allowed Arguments for '*Name*', *Value* Pairs

'*Name*'	*Value*	**Description**
SEASONALITY	Numeric	Seasonal cycle length (a positive integer)

DIAGNOSE Object Summary

DECLARE OBJECT obj(DIAGNOSE) defines a object that is used to generate (diagnose) time series models for a time series data. The DIAGNOSE object can be specified as input to perform automatic model selection and forecasting in the forecasting engine (FORENG) object.

DIAGNOSE Synopsis

Object declaration statement :

DECLARE OBJECT *obj* (**DIAGNOSE**) **;**

Method syntax:

rc = *obj*.**Initialize** (*TSDFObject*) **;**

rc = *obj*.**SetSpec** (*DIAGSPECObject*) **;**

rc = *obj*.**Replay** (*INDIAGObject*) **;**

rc = *obj*.**Run** ( ) **;**

rc = *obj*.**SetOption** ('*Name*', *Value* [,'*Name*', *Value*]) **;**

rc = *obj*.**GetModel** ('*Family*', *ModelXML*) **;**

Attribute summary:

nmodels = *obj*.**nmodels** () **;**

Table 1.10 summarizes the methods associated with the DIAGNOSE Object.

Table 1.10 Methods of the DIAGNOSE Object

DIAGNOSE Method	Description
Initialize	Initialize the DIAGNOSE object.
SetSpec	Set diagnostic controls
Replay	Replay diagnostic control specification
SetOption	Set named option
Run	Perform model generation
GetModel	Get model generation results
NModels	Get number of model families diagnosed

DIAGNOSE.Initialize Method

Usage: *rc* = *obj*.**Initialize** (*TSDFObject*) ;

Initialize a DIAGNOSE instance and specify the time series data for the DIAGNOSE instance.

Parameters

[in] *TSDFObject* The TSDF object that holds the time series data to be diagnosed by the DIAGNOSE instance. This method retains only a reference to the TSDF object's time series data frame and does not make a deep copy of its time series data.

DIAGNOSE.SetSpec Method

Usage: *rc* = *obj*.**SetSpec** (*DIAGSPECObject*) ;

Set diagnostic control options for the DIAGNOSE instance. Modified control settings in the DIAGSPEC object (DIAGSPECObject) are copied into the control settings for the DIAGNOSE instance for use by the next DIAGNOSE.Run method call.

Parameters

[in] *DIAGSPECObject* The DIAGSPEC instance that defines the diagnostic options to be used by the DIAGNOSE instance.

DIAGNOSE.Replay Method

Usage: *rc* = *obj*.**Replay** (*INDIAGObject*) ;

Restore a previously persisted diagnostic control specification from the specified INDIAG instance INDIAGObject. This method establishes the diagnostic control settings in a model identification run of the DIAGNOSE instance. For more information about persisting diagnostic control specifications, see the section "OUTDIAG Object Summary" on page 36.

Parameters

[in] *INDIAGObject* The INDIAG instance that specifies the source of the diagnostic control specification to restore.

DIAGNOSE.Run Method

Usage: *rc* = *obj*.**Run** ( ) ;

Run model diagnosis for the time series data frame that is specified for the DIAGNOSE instance. Table 1.11 shows the model families that might be considered during the diagnostic process.

Table 1.11 Model Families for the TSDF.Run Method

Family	Description
ESM	Seasonal and nonseasonal exponential smoothing models
ARIMAX	ARIMA model with predictors using ARIMA-REG order

Table 1.11 *continued*

Family	Description
REGARIMA	ARIMA model with predictors using REG-ARIMA order
UCM	UCM model with predictors
IDM	Intermittent demand (IDM) model

The default families considered include ESM and ARIMAX.

Parameters

There are no parameters associated with this method.

DIAGNOSE.SetOption Method

Usage: *rc* = *obj*.**SetOption** ('*Name*', *Value* [, '*Name*', *Value*]) ;

Set named option for the DIAGNOSE instance. '*Name*' is a character variable. The type of *Value* depends on the value of '*Name*'.

Parameters

[in] '*Name*' Character variable that names the option to set.

[in] *Value* Specifies the value for the named option.

Table 1.12 Allowed Options for DIAGNOSE.SetOption Method

'*Name*'	Value Type	Description
CRITERION	String	Selection statistic name
BACK	Numeric	Back region for model performance (a nonnegative integer)
HOLDOUT	Numeric	Holdout region for model selection (a nonnegative integer)

DIAGNOSE.GetModel Method

Usage: *rc* = *obj*.**GetModel** ('*Family*', *ModelXML*) ;

Fetch the model information by its family (identification technique) from the DIAGNOSE instance.

Parameters

[in] '*Family*' Character string whose value specifies the model information to return.

[out] *ModelXML* Character variable to receive the XML for the model.

Table 1.13 Allowed Arguments for '*Family*'

Family	Description
ESM	Generated ESM model
ARIMAX	Generated ARIMA model using ARIMA-REG order
REGARIMA	Generated ARIMA model using REG-ARIMA order
UCM	Generated UCM model
IDM	Generated IDM model

If no model is generated for the specified '*Family*', a zero-length string is returned. If the specified *ModelXML* character variable is too short to receive the XML string, a failure status is returned.

DIAGNOSE Attributes

DIAGNOSE.nmodels Method

Usage: *nmodels* = *obj*.**nmodels** *()* **;**

Return the number of models that are generated from the DIAGNOSE.Run() method. A missing value indicates that a Run() method has not been successfully completed since the last DIAGNOSE.SetData() method.

Parameters

There are no parameters associated with this method.

FORENG Object Summary

DECLARE OBJECT obj(FORENG) defines an object that is used to automate time series model selection and forecasting. The FORENG object can be used with the DIAGNOSE object and with various model specification objects from the TSM package.

FORENG Synopsis

Object declaration statement:

DECLARE OBJECT *obj* *(***FORENG***)* **;**

Method syntax:

rc = *obj*.**Initialize** *(TSDFObject)* **;**

rc = *obj*.**Initialize** *(DIAGNOSEObject)* **;**

rc = *obj*.**AddFrom** *(specObject)* ;

rc = *obj*.**Replay** *(infmsgObject [, inestObject])* ;

rc = *obj*.**Run** *( )* ;

rc = *obj*.**GetForecast** *(Which, Result)* ;

rc = *obj*. **GetXSeries** *(WhichX, XSeries)* ;

rc = *obj*.**SetOption** *('Name', Value [, 'Name', Value])* ;

Attribute summary:

nfor = *obj*.**nfor** *()* ;

criterion = *obj*.**criterion** *()* ;

Table 1.14 summarizes the methods that are associated with the FORENG object.

Table 1.14 Methods of FORENG Object

FORENG Method	Description
Initialize	Initialize the FORENG object with a TSDF object or DIAGNOSE object
AddFrom	Add models to the FORENG instance
Replay	Replay models and parameter estimates for theFORENG instance
SetOption	Set named option
Run	Run automatic model selection and forecast
GetForecast	Get forecast series
GetXSeries	Get X series that is used in final forecast
NFor	Get forecast series length
criterion	Get final forecast fit statistic

FORENG Methods

FORENG.Initialize Method

Usage: *rc* = *obj*.**Initialize** *(TSDFObject)* ;

Initialize the FORENG instance with the time series data frame to supply the data that it will use to forecast. Models can be added via the FORENG.AddFrom method prior to calling the FORENG.Run method. If no models are added before calling FORENG.Run(), the forecast is generated using ESMBEST.

Parameters

[in] *TSDFObject* The TSDF object that holds the time series data to be forecast by the FORENG instance.

FORENG.Initialize Method

Usage: *rc* = *obj*.**Initialize** *(DIAGNOSEObject)* ;

Initialize the FORENG instance to use the generated models and time series data frame from the specified DIAGNOSE instance.

Parameters

[in] *DIAGNOSEObject* The DIAGNOSE object that holds the time series data and generated model information that are used to initialize the FORENG instance.

FORENG.AddFrom Method

Usage: *rc* = *obj*.**AddFrom** *(specObject)* ;

Add models from a source instance in the FORENG object's model selection graph. Models can be included from the objects shown in Table 1.15.

Table 1.15 Model Objects for the FORENG.Run Method

Object	Description
SELSPEC	Includes the model selection specification
ESMSPEC	Includes the exponential smoothing model specification
UCMSPEC	Includes the UCM model specification
IDMSPEC	Includes the IDM model specification
ARIMASPEC	Includes the ARIMA model specification

NOTE:

1. For a model selection list, the list's models are appended to the FORENG instance's root selection list.
2. Calling FORENG.AddFrom subsequent to a FORENG instance results in a replay that augments the restored model selection graph with the models from the SpecObject and force TASK=SELECT for the subsequent FORENG.Run method.

Parameters

[in] *specObject* source of models to add.

FORENG.Replay Method

Usage: *rc* = *obj*.**Replay** *(infmsgObject [, inestObject])* **;**

Restore a previously persisted forecast model selection graph (FMSG) from the specified INFMSG instance. This establishes the context to allow for a model selection and forecasting run of the FORENG instance. Optionally, you can specify an INEST instance that supplies previously persisted parameter estimates for the restored FMSG. This determines the selected path (model set) from the restored FMSG and supplies the selected models with parameter estimates that are fixed for forecast-only runs or that serve as initial values for update runs. This method effectively provides the capability that is inherent in the TASK= modes for PROC HPFENGINE. If you restore a previously saved FMSG, you can call the FORENG.AddFrom method to augment the restored model set with other models as desired. When you restore the FMSG with a parameter set (INEST instance), the restored FMSG is pruned to reflect the selected path (model set), based on the parameter set. In either case, calling FORENG.AddFrom subsequent to a FORENG.Replay method always forces a model selection mode (TASK=SELECT) for the FORENG object. For more information about persisting FMSG specifications, see the section "OUTFMSG Object Summary" on page 48; for more information about persisting FMSG model parameter estimates, see the section "OUTEST Object Summary" on page 37.

Parameters

[in] *infmsgObject* source of the FMSG XML to restore. By default, restoring only the FMSG forces a model selection mode for the FORENG.Run method.

[in] *inestObject* optional argument that specifies source of the model parameter estimates to restore. This both subsets the FMSG model set to those that include parameter estimates and provides those selected models with their parameter estimates. By default, restoring both FMSG and parameter estimates forces a forecast-only mode for the FORENG.Run method. You can change this by using the FORENG.SetOption method.

FORENG.Run Method

Usage: *rc* = *obj*.**Run** *( )* **;**

Run model selection for the time series data frame that is specified for the FORENG instance. The FORENG instance model selection is driven by its FMSG content. Model selection is followed by a final forecast that uses the best performing model from the model selection step.

Parameters

There are no parameters associated with this method.

FORENG.GetForecast Method

Usage: *rc* = *obj*.**GetForecast** *(Which, Result)* **;**

Get the specified forecast series (*Which*) from the FORENG instance and store it in the specified numeric array (*Result*). *Which* is a case-insensitive character string.

Parameters

[in] *Which* Character string whose value specifies the forecast series to return

[out] *Result* Numeric array to receive the forecast series

Table 1.16 Allowed Arguments for *Which*

Which	**Meaning**
PREDICT	Prediction series
ERROR	Prediction errors
STDERR	Prediction standard error series
UPPER	Upper confidence limit series
LOWER	Lower confidence limit series

FORENG.GetXSeries Method

Usage: *rc* = *obj*. **GetXSeries** *(WhichX, XSeries)* ;

Get the specified X series (*WhichX*) from the FORENG instance and store it in the specified numeric array (*XSeries*). *WhichX* is a case-insensitive character string. If the specified X variable is not available in the FORENG instance, a failure status is returned. If the specified X variable is available and not used in the final forecast, the X series is returned and a warning status is returned.

Parameters

[in] *WhichX* Character string that specifies the name of the X series to return

[out] *XSeries* Numeric array to receive the X series

FORENG.SetOption Method

Usage: *rc* = *obj*.**SetOption** *('Name', Value [, 'Name', Value])* ;

Set the named option for the FORENG instance. '*Name*' is a character variable. The type of *Value* depends on the value of '*Name*'.

Parameters

[in] '*Name*' Character variable that names the option to set.

[in] *Value* Specifies the value for the named option.

Table 1.17 Allowed Arguments for '*Name*', *Value* Pairs

'*Name*'	**Value Type**	**Description**
ALPHA	Numeric	Significance level for forecast confidence bands (0 < *Value* < 1)
CRITERION	String	Fit statistic mnemonic. For more information, see the CRITERION= option in the PROC HPFDIAGNOSE statement in the HPFDIAGNOSE chapter in *SAS Forecast Server Procedures: User's Guide*
LEAD	Numeric	Forecast lead (a nonnegative integer)
BACK	Numeric	Back region (a nonnegative integer)
HOLDOUT	Numeric	Holdout region (a nonnegative integer)
HOLDOUTPCT	Numeric	Holdout percentage (0 ≤ *Value* ≤ 1.0)
TASK	String	Run task (SELECT, FORECAST, FIT, UPDATE)
HORIZON	Numeric	Forecast horizon reference time

FORENG Attributes

FORENG.nfor Method

Usage: *nfor* **=** *obj*.**nfor** *()* **;**

Return the length (observation count) of the forecast series for the FORENG instance. A missing value indicates that the FORENG instance has not produced a successful forecast.

FORENG.criterion Method

Usage: *criterion* **=** *obj*.**criterion** *()* **;**

Returns the fit statistic value for the final forecast for the FORENG instance. The criterion is set via the FORENG.SetOption method. A missing value indicates that the FORENG instance has not produced a successful forecast.

Parameters

There are no parameters associated with this method.

DIAGSPEC Object Summary

DECLARE OBJECT obj(DIAGSPEC) defines an object that is used as a control specification for a time series model identification process. You can configure this object so that appropriate time series model families are included in the search process. You can also configure this object to set various other search options.

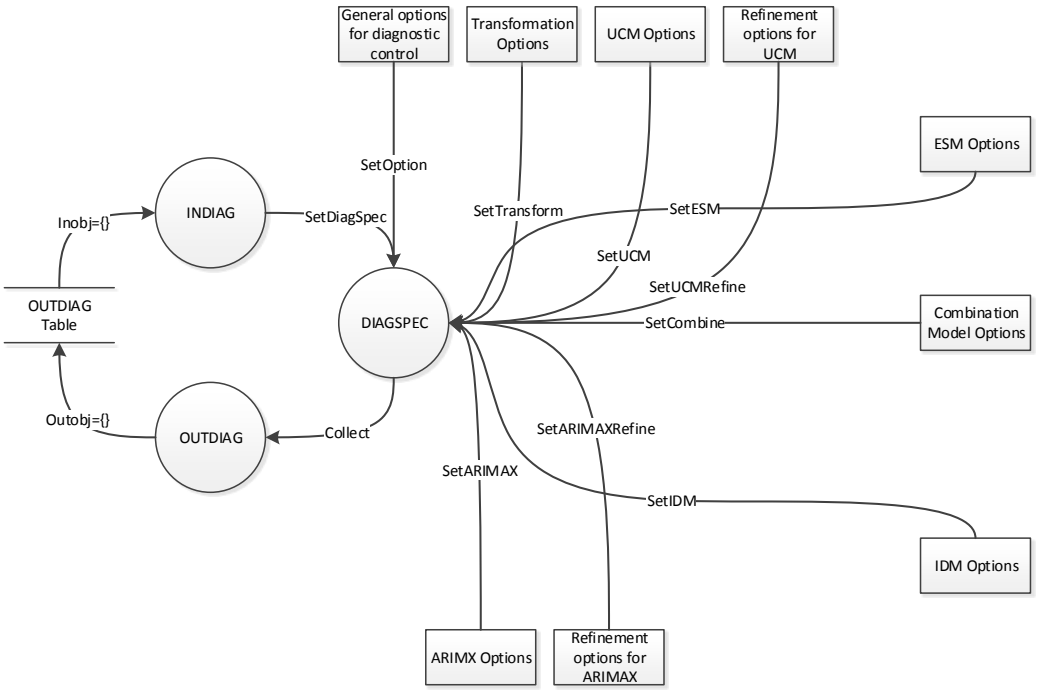
Table 1.18 lists the time series model families that are supported.

Table 1.18 DIAGSPEC Model Families

Family	Description
ESM	Exponential smoothing models
ARIMA	ARIMA/ARIMAX models
IDM	Intermittent demand models (Croston's model and average demand model)
UCM	Unobserved component models

Once configured, the DIAGSPEC object can be used to set the search settings of the DIAGNOSE object (DIAGNOSEObject.SetSpec(DIAGSPECObject)). In turn, this DIAGNOSE object searches for appropriate models for the target series in the data frame that initialized the DIAGNOSE object. Figure 1.2 diagrams the different methods of the DIAGSPEC object.

Figure 1.2 DIAGSPEC Data Flow



DIAGSPEC Synopsis

Object declaration statement:

DECLARE OBJECT *obj* (**DIAGSPEC**) ;

Method syntax:

rc = *obj*.**Open** ( ) ;

rc = *obj*.**Close** () ;

rc = *obj*.**SetOption** ('Name',Value['Name',Value,...]) ;

rc = *obj*.**SetARIMAX** ('Name',Value['Name',Value,...]) ;

rc = *obj*.**SetARIMAXRefine** ('Name',Value['Name',Value,...]) ;

rc = *obj*.**SetESM** (['Name',Value,'Name',Value,...]) ;

rc = *obj*.**SetIDM** (['Name',Value,'Name',Value,...]) ;

rc = *obj*.**SetTransform** (['Name',Value,'Name',Value,...]) ;

rc = *obj*.**SetTrend** (['Name',Value,'Name',Value,...]) ;

rc = *obj*.**SetUCM** (['Name',Value,'Name',Value,...]) ;

rc = *obj*.**SetUCMRefine** (['Name',Value,'Name',Value,...]) ;

Table 1.19 summarizes the methods that are associated with the DIAGSPEC Object.

Table 1.19 Methods of the DIAGSPEC Object

DIAGSPEC Method	Description
Open	Open the DIAGSPEC object
Close	Close the DIAGSPEC object
SetOption	Set overall control options
SetTransform	Set transform test options
SetTrend	Set trend test options
SetESM	Set ESM diagnostic options
SetIDM	Set IDM diagnostic options
SetARIMAX	Set ARIMA diagnostic options
SetARIMAXRefine	Set ARIMA parameter refinement options
SetUCM	Set UCM diagnostic options
SetUCMRefine	Set UCM parameter refinement options

The following remarks apply to '*Name*', *Value* pairs in the various DIAGSPEC methods:

1. '*Name*' values are always case-insensitive.

2. *Value* values that require string types are case-insensitive unless otherwise noted.

The DIAGSPEC.Open method always resets the object's diagnostic control options to their default settings. By default, ARIMA and ESM model family diagnostics are enabled. Sometimes you might want to enable other model families with their default diagnostic control options. You can call the DIAGSPEC methods that are related to the different model families without any arguments to affect enablement of the diagnostic tests for that model family with the associated default diagnostic control options. These property methods differ from the others that require at least one '*Name*'/*Value* pair.

Methods that can be called with no arguments include:

- SetESM
- SetIDM
- SetARIMAX
- SetARIMAXRefine
- SetUCM
- SetUCMRefine

In all of these cases, calling the DIAGSPEC methods with no arguments always resets the associated diagnostic control options to defaults regardless of preceding calls to the DIAGSPEC method that you might have made to change associated settings. Further details are provided in the descriptions of the various DIAGSPEC methods.

DIAGSPEC Methods

DIAGSPEC.Open Method

Usage: *rc* = *obj*.**Open** *( )* **;**

Open the DIAGSPEC instance for configuration. This initializes an empty diagnostic specification.

Parameters

There are no parameters associated with this method.

DIAGSPEC.Close Method

Usage: *rc* = *obj*.**Close** *()* **;**

Finalize the diagnostic settings in the DIAGSPEC instance. This prepares DIAGSPEC to be used in a DIAGNOSE instance or to be imported to a DIAGSPEC instance for printing or storage to a specification repository catalog.

Parameters

There are no parameters associated with this method.

DIAGSPEC.SetOption Method

Usage: *rc* = *obj*.**SetOption** *('Name',Value[,'Name',Value,...])* ;

Set named option for the DIAGSPEC instance. '*Name*' is a character variable. The type of *Value* depends on the value of '*Name*'.

Parameters

[in] '*Name*' Character variable that names the option to set.

[in] *Value* Specifies the value for the named option.

Table 1.20 Allowed Arguments for 'Name', Value Pairs

Name	Value Type	Value
SIGLEVEL	Numeric	Significance level. Must be between 0 and 1.
CRITERION	String	Fit statistic mnemonic. For more information, see the CRITERION= option in the PROC HPFDIAGNOSE statement in the HPFDIAGNOSE chapter in *SAS Forecast Server Procedures: User's Guide*. The default is RMSE.
INPUTMISSPCT	Numeric	Input missing percentage. Must be between 0 and 1.
ENTRYPCT	Numeric	AIC or SBC improvement percentage. Must be between 0 and 1.
PREFILTER	String	Prefilter control (YES, MISSING, EXTREME, or BOTH). The default is YES.
DELAYINPUT	Numeric	Input variable lag. Must be a nonnegative value.
DELAYEVENT	Numeric	Event variable lag. Must be a nonnegative value.
TESTINPUT	String	Test input control (NONE, TRANSFORM, TREND, or BOTH. The default is NONE.
SELECTINPUT	String	Select input control (SELECT or ALL). The default is SELECT.
SELECTINPUT	Numeric	Best N input variables. Must be a value no less than 1.

DIAGSPEC.SetARIMAX Method

Usage: *rc* = *obj*.**SetARIMAX** *('Name', Value['Name',Value,...])* ;

Set control options for ARIMAX model diagnostics to be performed. '*Name*' is a character variable. The type of *Value* depends on the value of '*Name*'.

Parameters

[in] '*Name*' Character variable that names the option to set.

[in] *Value* Specifies the value for the named option.

Table 1.21 Allowed Arguments for 'Name', Value Pairs

Name	Value Type	Value
SIGLEVEL	Numeric	Significance level. A number between 0 and 1.
PERROR	Array[2]	AR order for MINIC error. (PERROR[1]=Min, PERROR[2]=Max)
P	Array[2]	Nonseasonal AR order range. (P[1]=Min, P[2]=Max)
Q	Array[2]	Nonseasonal MA order range. (Q[1]=Min, Q[2]=Max)
PS	Array[2]	Seasonal AR order range. (PS[1]=Min, PS[2]=Max)
QS	Array[2]	Seasonal MA order range. (QS[1]=Min, QS[2]=Max)
XNUM	Array[2]	Transfer function numerator order range. (XNUM[1]=Min, XNUM[2]=Max)
XDEN	Array[2]	Transfer function denominator order range. (XDEN[1]=Min, XDEN[2]=Max)
CRITERION	String	Identification criterion (AIC or SBC). The default is SBC.
ESTMETHOD	String	ARIMA estimation method (ULS, CLS, or ML). The default is CLS.
METHOD	String	Tentative ARMA orders (MINIC, SCAN, or ESACF). The default is MINIC.
IDENTIFY	String	Identification order (ARIMA, REG, or BOTH). The default is ARIMA.
NOINT	Numeric	Suppress constant term (0 | 1). The default is 0 or no constant term.

AIC is Akaike's information criterion, SBC is the Schwarz Bayesian information criterion, MINIC is the minimum information criterion, SCAN is the smallest canonical correlation analysis, and ESACF is the extended sample autocorrelation function.

DIAGSPEC.SetARIMAXRefine Method

Set ARIMA parameter refinement options

Usage: *rc* = *obj*.**SetARIMAXRefine** *('Name',Value['Name',Value,...])* ;

Set control options for ARIMAX model parameter refinement. '*Name*' is a character variable. The type of *Value* depends on the value of '*Name*'.

Parameters

[in] '*Name*' Character variable that names the option to set.

[in] *Value* Specifies the value for the named option.

Table 1.22 Allowed Arguments for '*Name*', *Value* Pairs

'*Name*'	**Value Type**	*Value*
SIGLEVEL	Numeric	Significance level. A number between 0 and 1.
ORDER	String	Order of diagnosing model components. The default is INPUT.

Table 1.23 shows the valid ORDER argument values.

Table 1.23 Allowed Arguments for ORDER

Value	**Meaning**
ARMA:INPUT	Test ARMA coefficients before predictor coefficients
INPUT:ARMA	Test predictor coefficients before ARMA coefficients

A SetARIMAXRefine method call with no arguments enables ARIMA model diagnosis and sets default options for ARIMA refinement.

DIAGSPEC.SetESM Method

Usage: *rc* = *obj*.**SetESM** *(['Name',Value,'Name',Value,...])* ;

Set control options for ESM testing to be performed.'*Name*' is a character variable. The type of *Value* depends on the value of '*Name*'. A SetESM method call with no arguments enables ESM diagnosis with the default options.

Parameters

[in] '*Name*' Character variable that names the option to set.

[in] *Value* Specifies the value for the named option.

Table 1.24 Allowed Arguments for '*Name*', *Value* Pairs

'*Name*'	**Value Type**	*Value*
SIGLEVEL	Numeric	Significance level. Must be between 0 and 1.
METHOD	String	ESM method. The default is BEST.

Table 1.25 shows the valid values for Method.

Table 1.25 Valid Values for METHOD

Value	Meaning
SIMPLE	Simple (single) exponential smoothing
DOUBLE	Double (Brown) exponential smoothing
LINEAR	Linear (Holt) exponential smoothing
DAMPTREND	Damped trend exponential smoothing
ADDSEASONAL	Additive seasonal exponential smoothing
MULTSEASONAL	Multiplicative seasonal exponential smoothing
SEASONAL	Same as ADDSEASONAL
WINTERS	Winters multiplicative method
ADDWINTERS	Winters additive method
BEST	Best candidate smoothing model (SIMPLE, LINEAR, DAMPTREND), (ADDSEASONAL, ADDWINTERS, or WINTERS)
BESTN	Best candidate nonseasonal smoothing model (SIMPLE, LINEAR, or DAMPTREND)
BESTS	Best candidate seasonal smoothing model (ADDSEASONAL, ADDWINTERS, or WINTERS)

DIAGSPEC.SetIDM Method

Set IDM diagnostic options

Usage: *rc* = *obj*.**SetIDM** *(['Name',Value,'Name',Value,...])* **;**

Set control options for IDM testing to be performed.'*Name*' is a character variable. The type of *Value* depends on the value of '*Name*'. The following table lists the allowed options:

Parameters

[in] '*Name*' Character variable that names the option to set.

[in] *Value* Specifies the value for the named option.

Table 1.26 Allowed Arguments for '*Name*', Value Pairs

'*Name*'	Value Type	*Value*
INTERMITTENT	Numeric	Intermittency threshold (the default is 2)
BASE	Numeric	Base value for demand series (the default is AUTO)

Table 1.26 *continued*

'*Name*'	**Value Type**	*Value*
METHOD	String	IDM method (CROSTON, AVERAGE, or BEST; the default is BEST)
TRANSFORM	Numeric	Transform (same values as SetTransform)
TRANSPARM	Numeric	Transform parameter (Box-Cox only)

A SetIDM method call with no parameters enables IDM diagnosis with the default options.

DIAGSPEC.SetTransform Method

Usage: *rc* = *obj*.**SetTransform** *(['Name',Value,'Name',Value,...])* **;**

Set control options for functional transform testing to be performed.'*Name*' is a character variable. The type of *Value* depends on the value of '*Name*'.

Parameters

[in] '*Name*' Character variable that names the option to set.

[in] *Value* Specifies the value for the named option.

Table 1.27 Allowed Arguments for '*Name*', *Value* Pairs

'*Name*'	**Value Type**	*Value*
SIGLEVEL	Numeric	Significance level ($0 \leq$ *Value* ≤ 1.0)
P	Numeric	AR order for log transform test
TRANSFORM	String	Transform to use (the default is NONE)
TRANSPARM	Numeric	Transform parameter (Box-Cox only)
TRANSOPT	String	Inverse forecasts (MEAN or MEDIAN; the default is MEAN)

DIAGSPEC.SetTrend Method

Usage: *rc* = *obj*.**SetTrend** *(['Name',Value,'Name',Value,...])* **;**

Set control options for trend testing to be performed.'*Name*' is a character variable. The type of *Value* depends on the value of '*Name*'.

Parameters

[in] '*Name*' Character variable that names the option to set.

[in] *Value* Specifies the value for the named option.

Table 1.28 Valid Values for '*Name*', *Value* Pairs

'*Name*'	**Value Type**	*Value*
SIGLEVEL	Numeric	Significance level ($0 \leq$ *Value* ≤ 1.0)
P	Numeric	AR order for ADF/seasonality tests.
DIFF	String	Simple differencing (NONE or AUTO)
DIFFN	Numeric	Forced simple differencing order (DIFF=n)
DIFFRAN	Numeric	Tests simple differencing range (DIFF=(0:n))
SDIFF	String	Seasonal differencing (NONE or AUTO)
SDIFFN	Numeric	Forced seasonal differencing (SDIFF=n)

DIAGSPEC.SetUCM Method

Usage: *rc* = *obj*.**SetUCM** *(['Name',Value,'Name',Value,...])* **;**

Set control options for UCM model diagnostics to be performed.'*Name*' is a character variable. The type of *Value* depends on the value of '*Name*'.

Parameters

[in] '*Name*' Character variable that names the option to set.

[in] *Value* Specifies the value for the named option.

Table 1.29 Allowed Arguments for'*Name*', *Value* Pairs

'*Name*'	**Value Type**	*Value*
SIGLEVEL	Numeric	Significance level ($0 \leq$ *Value* ≤ 1.0)
IRREGULAR	Numeric	Test IRREGULAR component (0 or 1, default=1)
LEVEL	Numeric	Test LEVEL component (0 or1; the default is 1)
SLOPE	Numeric	Test SLOPE component (0 or1; the default is 1)
SEASON	Numeric	Test SEASON component (0 or1; the default is 0)
CYCLE	Numeric	Test CYCLE component (0 or1; the default is 0)
AUTOREG	Numeric	Test AUTOREG component (0 or1; the default is 0)
DEPLAG	Numeric	Test DEPLAG component (0 or1; the default is 0)
ALL	Numeric	Include all components (0 or1; the default is 0)

A SetUCM method call with no parameters enables UCM diagnosis with the default options, which includes defaults for UCM refinement.

DIAGSPEC.SetUCMRefine Method

Usage: *rc* = *obj*.**SetUCMRefine** *(['Name',Value,'Name',Value,...])* **;**

Set control options for UCM model diagnostics to be performed.'*Name*' is a character variable. The type of *Value* depends on the value of '*Name*'.

Parameters

[in] '*Name*' Character variable that names the option to set.

[in] *Value* Specifies the value for the named option.

Table 1.30 Allowed Arguments for '*Name*', *Value* Pairs

'*Name*'	**Value Type**	*Value*
SIGLEVEL	Numeric	Significance level ($0 \leq$ *Value* ≤ 1.0)
ORDER	String	Order of subsetting UCM components (the default is INPUT)

A SetUCM method call with no specified parameters enables UCM diagnosis with the default options. This includes defaults for UCM refinement. A SetUCMRefine method call with no specified parameters enables UCM diagnosis and sets default options for UCM refinement.

SELSPEC Object Summary

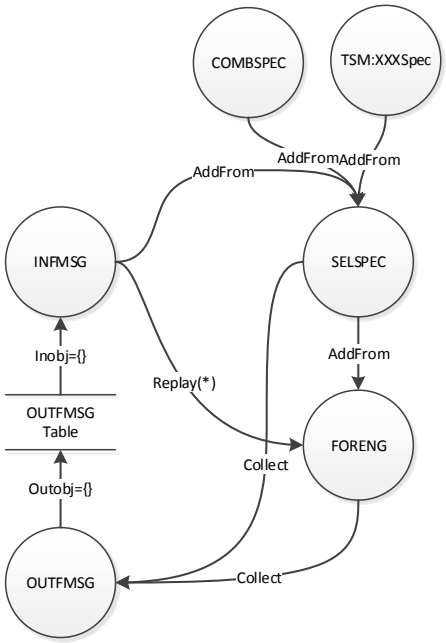
DECLARE OBJECT obj(SELSPEC) defines an object that is used to define and manipulate forecast model selection list (MSL) objects. The MSL defines a model-based selection strategy for forecasting a dependent variable given a historical information set (TSDF). The MSL is a directed acyclic graph (DAG) of time series models, and model selection lists that are evaluated to determine the best performing forecast. Competing forecasts are evaluated subject to rules that are defined in the MSL and in the FORENG object that evaluates the MSL. Upon evaluation, a final forecast is produced from the best performing forecast. Abstractly, the best performing forecast is properly viewed as a path in the MSL DAG. The SELSPEC object offers functionality comparable to the HPFSELECT procedure. SELSPEC objects accept models and subgraphs from these sources:

Object	Use
DIAGNOSE	Generated models to include
SELSPEC	Subgraph to include
INFMSG	Restored SELSPEC models to include
ESMSPEC	ESM model to include
ARIMASPEC	ARIMA model to include
UCMSPEC	UCM model to include
IDMSPEC	IDM model to include

ESMSPEC, ARIMASPEC, UCMSPEC, and ICMSPEC objects are found in the TSM package.

Figure 1.3 diagrams the different methods of the SELSPEC object.

Figure 1.3 SELSPEC Data Flow



SELSPEC Synopsis

Object declaration statement:

DECLARE OBJECT *obj* (**SELSPEC**) **;**

Method syntax:

rc **=** *obj***.Open** *(nspecs)* **;**

rc **=** *obj***.Close** *()* **;**

rc **=** *obj***.AddFrom** *(SourceObj [,ListIndex])* **;**

rc **=** *obj***.SetOption** *('Name', Value)* **;**

rc **=** *obj***.SetDiagnose** *('Name', Value)* **;**

Table 1.32 summarizes the methods that are associated with the SELSPEC Object.

Table 1.32 Methods of SELSPEC Object

SELSPEC Method	Description
Open	Open SELSPEC for editing
Close	Close SELSPEC for editing
SetDiagnose	Set diagnose options
SetOption	Set named option
AddFrom	Add from the specified source to the SELSPEC object

SELSPEC Methods

SELSPEC.AddFrom Method

Usage: *rc* **=** *obj***.AddFrom** *(SourceObj [,ListIndex])* **;**

Add FMSG nodes from the specified source object to the SELSPEC instance. The optional *ListIndex* enables you to specify the 1-relative index in the SELSPEC's model list where the included DAG is to be placed.

Parameters

[in] *SourceObj* Source for models to be added to the SELSPEC instance

[in] *ListIndex* The index in the SELSPEC instance list where the model DAG from the *SourceObj* is to be inserted. If this parameter is not specified, the DAG from the *SourceObj* is inserted at the next available list index.

Table 1.33 Allowed Arguments for *SourceObj*

Object	Package	Behavior
SELSPEC	ATSM	SELSPEC object's DAG
DIAGNOSE	ATSM	DIAGNOSE object's generated models
FORENG	ATSM	Current FORENG FMSG
INFMSG	ATSM	INFMSG XML
ESMSPEC	TSM	Model from the ESMSPEC object
ARIMASPEC	TSM	Model from the ARIMASPEC object
UCMSPEC	TSM	Model from the UCMSPEC object
IDMSPEC	TSM	Model from the IDMSPEC object
TSM	TSM	Model from the TSM object

SELSPEC.Close Method

Usage: *rc* = *obj*.**Close** *()* **;**

Close SELSPEC object for editing. Consistency checks are performed to ensure that the model set that is defined for the SELSPEC is completely determined. This means that models must have definitions in the SELSPEC instance before it is closed. Failure to ensure this means that the SELSPEC content is nullified for subsequent use in other ATSM package interactions. For example, if the SELSPEC includes a specification name for which no XML is defined, then a consistency check failure occurs.

Parameters

There are no parameters associated with this method.

SELSPEC.Open Method

Usage: *rc* = *obj*.**Open** *(nspecs)* **;**

Open SELSPEC object for construction of a model selection list.

Parameters

[in] *nspecs* Numeric variable that specifies the number of model specification slots to be defined in the FMSG list.

SELSPEC.SetDiagnose Method

Usage: *rc* = *obj*.**SetDiagnose** *('Name', Value)* **;**

Set options for selection diagnostics.

Parameters

[in] '*Name*' Character string that specifies the option name.

[in] *Value* variable that specifies a value of the option to be set. The type of *Value* depends on the option '*Name*'.

Table 1.34 Allowed Arguments for '*Name*', *Value* Pairs

'*Name*'	**Value Type**	*Value*
IDMBASE	Numeric	IDM base value (Missing==>Automatic)
INTERMITTENT	Numeric	Intermittency threshold ($0 \leq$ *Value*)
SEASONTEST	Numeric	Filter models using seasonality test (0 or 1)
LOGTEST	Numeric	Filter models using log test (0 or 1)

SELSPEC.SetOption Method

Usage: *rc* = *obj*.**SetOption** *('Name', Value)* **;**

Set named options for SELSPEC object.

Parameters

[in] '*Name*' Character string that specifies the option name.

[in] *Value* variable that specifies a value of the option to be set. The type of *Value* depends on the option '*Name*'.

Table 1.35 Allowed Arguments for '*Name*', Value Pairs

'*Name*'	**Value Type**	*Value*
ALPHA	Numeric	Alpha value ($0 \leq$ *Value* ≤ 1.0)
CRITERION	String	Fit statistic mnemonic. For more information, see the CRITERION= option in the PROC HPFDIAGNOSE statement in the HPFDIAGNOSE chapter in *SAS Forecast Server Procedures: User's Guide*
HOLDOUT	Numeric	Holdout region (a positive integer)
HOLDOUTPCT	Numeric	Holdout percentage ($0 \leq$ *Value* ≤ 1.0)
CHOOSE	String	Preselect model with this name

OUTDIAG Object Summary

DECLARE OBJECT obj(OUTDIAG) defines an object that is used to persist diagnostic control specifications.

Column	Type	Description
NAME	String	Name of the dependent variable (can be missing)
_SPECNAME	Numeric	Name of the diagnostic specification
SPECLEN	Numeric	Length of the diagnostic specification XML
DIAGSPEC	String	Diagnostic specification XML document

OUTDIAG Synopsis

Object declaration statement:

DECLARE OBJECT *obj* (**OUTDIAG**) **;**

Method syntax:

rc **=** *obj***.Collect** *(SourceObject)* **;**

Attributes summary:

nrows **=** *obj***.nrows** *()* **;**

Table 1.37 summarizes the methods that are associated with the OUTDIAG Object.

Table 1.37 Methods of the OUTDIAG Object

OUTDIAG Method	Description
Collect	Collect diagnostic specification from OUTDIAG object
nrows	Number of rows in OUTDIAG object

OUTDIAG Methods

OUTDIAG.Collect Method

Usage: *rc* **=** *obj***.Collect** *(SourceObject)* **;**

Collect the diagnostic control specification from source object.

Parameters

[in] *SourceObject* The instance to be used as the source of the diagnostic control option specification to be persisted.

Table 1.38 Allowed Arguments for SourceObject

SourceObject	**Description**
DIAGNOSE	Renders DIAGSPEC XML from DIAGNOSE instance
DIAGSPEC	Renders DIAGSPEC XML from DIAGSPEC instance

OUTDIAG Attributes

OUTDIAG.nrows Method

Usage: *nrows* **=** *obj*.**nrows** *()* **;**

Query the OUTDIAG object for its current row count.

OUTEST Object Summary

DECLARE OBJECT obj(OUTEST) defines an object that is used to collect parameter estimates from a FORENG instance. The CAS table schema that is used for storing the parameter estimates is compatible with that used by PROC HPFENGINE for its OUTEST= data set.

Column	**Type**	**Description**
NAME	String	Name of the dependent variable
SELECT	Numeric	Name of the selection list
MODEL	Numeric	Name of model in the selection list
MODELVAR	String	Symbol used in the model specification
DSVAR	String	Corresponding variable name
VARTYPE	String	Type of the variable (dependent or independent)
TRANSFORM	String	Transform that is used for the dependent variable
COMPONENT	String	Component name within the component model
COMPMODEL	String	Component model name
PARM	String	Parameter name

Table 1.39 *continued*

Column	Type	Description
FACTOR	Numeric	Factor number
LAG	Numeric	Lag that is used
SHIFT	Numeric	Shift that is used
EST	Numeric	Parameter estimate
STDERR	Numeric	Parameter estimate standard error
TVALUE	Numeric	*t* statistic for parameter estimate
PVALUE	Numeric	*p*-value for parameter estimate
LABEL	String	System-generated label for model

OUTEST Synopsis

Object declaration statement:

DECLARE OBJECT *obj* (**OUTEST**) **;**

Method syntax:

rc **=** *obj***.Collect** *(FORENGObj)* **;**

Attributes summary:

nrows **=** *obj***.nrows** *()* **;**

Table 1.40 summarizes the methods that are associated with the OUTEST Object.

Table 1.40 Methods of the OUTEST Object

OUTEST Method	Description
Collect	Collect parameter estimates from the FORENG instance
nrows	Get the OUTEST row count

OUTEST Methods

OUTEST.Collect Method

Usage: *rc* = *obj*.**Collect** *(FORENGObj)* ;

Collect the parameter estimates from the FORENG instance *FORENGObj*.

Parameters

[in] *FORENGObj* specifies the FORENG object instance to use as the source of time series model parameter estimates.

OUTEST Attributes

OUTEST.nrows Method

Usage: *nrows* = *obj*.**nrows** *()* ;

Get the current row count from the OUTEST instance.

Parameters

There are no parameters associated with this method.

OUTFOR Object Summary

DECLARE OBJECT obj(OUTFOR) defines an object that is used to collect forecast series from a FORENG instance. The CAS table schema that is used for storing the set of forecast series variables is compatible with that used by PROC HPFENGINE for its OUTFOR= data set.

Table 1.41 Contents of the OUTFOR Object

Column	Type	Description
NAME	String	Name of the dependent variable
TIMEID	Numeric	Uniform time ID values for series
ACTUAL	Numeric	Accumulated values of dependent variable
PREDICT	Numeric	Forecasts of dependent variable
ERROR	Numeric	Residuals
STD	Numeric	Prediction standard error
UPPER	Numeric	Upper confidence limit
LOWER	Numeric	Lower confidence limit

OUTFOR Synopsis

Object declaration statement:

DECLARE OBJECT *obj* (**OUTFOR**) **;**

Method syntax:

rc **=** *obj***.Collect** *(FORENGObj[,Region])* **;**

Attributes summary:

rc **=** *obj***.nrows** *()* **;**

Table 1.42 summarizes the methods that are associated with the OUTFOR Object.

Table 1.42 Methods of the OUTFOR Object

OUTFOR Method	Description
Collect	Collect forecasts estimates from FORENG instance.
nrows	Get the OUTFOR row count.

OUTFOR Methods

OUTFOR.Collect Method

Usage: *rc* **=** *obj***.Collect** *(FORENGObj[,Region])* **;**

Collect the forecast series from the FORENG instance forecast object. An optional *Region* parameter can be specified to indicate the forecast region to be collected.

Parameters

[in] *FORENGObj* The FORENG object instance to use as the source of time series model parameter estimates.

[in] *Region* (Optional) The time region to be collected (the default is ALL).

Table 1.43 Allowed Arguments for Region

Value	Meaning
String	Collection region(ALL, FIT, or HORIZON; the default is ALL)
Numeric[2]	Numeric[1]=Start time ID, Numeric[2]=End time ID (the default is missing)

OUTFOR Attributes

OUTFOR.nrows Method

Usage: *rc* = *obj*.**nrows** *()* ;

Get the current row count from the OUTFOR instance.

Parameters

There are no parameters associated with this method.

OUTCOMP Object Summary

DECLARE OBJECT obj(OUTCOMP) defines an object that is used to collect component series from a FORENG instance. The CAS table schema that is used for storing the set of forecast component series variables is compatible with that used by PROC HPFENGINE for its OUTCOMP= data set.

Table 1.44 Contents of the OUTCOMP Object

Column	Type	Description
NAME	String	Name of the dependent variable
COMP	String	Name of the forecast component series
TIMEID	Numeric	Uniform time ID values for series
ACTUAL	Numeric	Accumulated values of dependent variable
PREDICT	Numeric	Forecasts of dependent variable
STD	Numeric	Prediction standard error
UPPER	Numeric	Upper confidence limit
LOWER	Numeric	Lower confidence limit

OUTCOMP Synopsis

Object declaration statement:

DECLARE OBJECT *obj* *(***OUTCOMP***)* ;

Method syntax:

rc = *obj*.**Collect** *(FORENGObj[,Region])* ;

Attributes summary:

rc = *obj*.**nrows** *()* ;

Table 1.45 summarizes the methods that are associated with the OUTCOMP Object.

Table 1.45 Methods of the OUTCOMP Object

OUTCOMP Method	Description
Collect	Collect forecasts estimates from the FORENG instance.
nrows	Get the OUTCOMP row count.

OUTCOMP Methods

OUTCOMP.Collect Method

Usage: *rc* = *obj*.**Collect** *(FORENGObj[,Region])* ;

Collect the model component series from the FORENG instance *FORENGObj*. An optional *Region* parameter can be specified to indicate the component series region to be collected.

Parameters

[in] *FORENGObj* The FORENG object instance to use as the source of time series model component series.

[in] *Region* (Optional) The time region to be collected (the default is ALL).

Table 1.46 Allowed Arguments for Region

Value	Meaning
String	Collection region (ALL, FIT, or HORIZON; the default is ALL)
Numeric[2]	Numeric[1]=Start time ID, Numeric[2]=End time ID (missing=default)

OUTCOMP Attributes

OUTCOMP.nrows Method

Usage: *rc* = *obj*.**nrows** *()* ;

Get the current row count from the OUTCOMP instance.

Parameters

There are no parameters associated with this method.

OUTINDEP Object Summary

DECLARE OBJECT obj(OUTINDEP) defines an object that is used to collect the series for independent variables that are used in the forecast from a FORENG instance. The CAS table schema that is used for storing the independent variable series is compatible with that used by PROC HPFENGINE for its OUTINDEP= data set.

Table 1.47 Contents of the OUTINDEP Object

Column	Type	Description
NAME	String	Name of the dependent variable
XVAR	String	Name of the independent variable
TIMEID	Numeric	Uniform time ID values for series
X	Numeric	Independent (X) variable value

OUTINDEP Synopsis

Object declaration statement:

DECLARE OBJECT *obj* (**OUTINDEP**) **;**

Method syntax:

rc **=** *obj***.Collect** *(FORENGObj)* **;**

Attributes summary:

rc **=** *obj***.nrows** *()* **;**

Table 1.48 summarizes the methods that are associated with the OUTINDEP Object.

Table 1.48 Methods of the OUTINDEP Object

OUTINDEP Method	Description
Collect	Collect the independent variable series that are used in the forecast from the FORENG instance forecast object.
nrows	Get the OUTINDEP row count.

OUTINDEP Methods

OUTINDEP.Collect Method

Usage: *rc* = *obj*.**Collect** *(FORENGObj)* ;

Collect the independent variable series that are used in the forecast from the FORENG instance *FORENGObj*.

Parameters

[in] *FORENGObj* The FORENG object instance to use as the source of time series model independent variable series.

OUTINDEP Attributes

OUTINDEP.nrows Method

Usage: *rc* = *obj*.**nrows** *()* ;

Get the current row count from the OUTINDEP instance.

Parameters

There are no parameters associated with this method.

OUTMODELINFO Object Summary

DECLARE OBJECT obj(OUTMODELINFO) defines an object that is used to collect characteristics of the selected model from a FORENG instance. The CAS table schema that is used for storing model information is compatible with that used by PROC HPFENGINE for its OUTMODELINFO= data set.

Table 1.49 Contents of the OUTMODELINFO Object

Column	Type	Description
NAME	String	Name of the dependent variable
MODEL	String	Name of the selected model specification
MODELTYPE	String	Type of model (ESM, ARIMA, UCM, or IDM)
DEPTRANS	String	Dependent variable transform used
SEASONAL	Numeric	Seasonal model (0 or 1 indicator)
TREND	Numeric	Trend model (0 or 1 indicator)
INPUTS	Numeric	Number of input variables in the model
EVENTS	Numeric	Number of events in the model

Table 1.49 *continued*

Column	Type	Description
OUTLIERS	Numeric	Number of outlier events in the model
STATUS	Numeric	Execution status of the model
SOURCE	String	Named source of the model

OUTMODELINFO Synopsis

Object declaration statement:

DECLARE OBJECT *obj* (**OUTMODELINFO**) **;**

Method syntax:

rc **=** *obj***.Collect** *(FORENGObj)* **;**

Attributes summary:

rc **=** *obj***.nrows** *()* **;**

Table 1.50 summarizes the methods that are associated with the OUTMODELINFO Object.

Table 1.50 Methods of the OUTMODELINFO Object

OUTMODELINFO Method	Description
Collect	Collect the model selection information from the FORENG instance *FORENGObj*.
nrows	Get the current row count from the OUTMODELINFO instance.

OUTMODELINFO Methods

OUTMODELINFO.Collect Method

Usage: *rc* **=** *obj***.Collect** *(FORENGObj)* **;**

Collect the model selection information from the FORENG instance *FORENGObj*.

Parameters

[in] *FORENGObj* specifies the FORENG object instance to use as the source of time series model selection fit statistics.

OUTMODELINFO Attributes

OUTMODELINFO.nrows Method

Usage: *rc* = *obj*.**nrows** *()* ;

Get the current row count from the OUTMODELINFO instance.

Parameters

There are no parameters associated with this method.

OUTSELECT Object Summary

DECLARE OBJECT obj(OUTSELECT) defines an object that is used to collect model selection statistics from a FORENG instance. The CAS table schema that is used for storing the fit statistics is compatible with that used by PROC HPFENGINE for its OUTSELECT= data set.

OUTSELECT Synopsis

Object declaration statement:

DECLARE OBJECT *obj* *(***OUTSELECT***)* ;

Method syntax:

rc = *obj*.**Collect** *(FORENGObj)* ;

Attributes summary:

rc = *obj*.**nrows** *()* ;

Table 1.51 summarizes the methods associated with the OUTSELECT Object.

Table 1.51 Methods of the OUTSELECT Object

OUTSELECT Method	Description
Collect	Collect the model selection fit statistics from the FORENG instance *FORENGObj*.
nrows	Get the current row count from the OUTSELECT instance.

OUTSELECT Methods

OUTSELECT.Collect Method

Usage: *rc* = *obj*.**Collect** *(FORENGObj)* ;

Collect the model selection fit statistics from the FORENG instance *FORENGObj*.

Parameters

[in] *FORENGObj* The FORENG object instance to use as the source of time series model selection fit statistics.

OUTSELECT Attributes

OUTSELECT.nrows Method

Usage: *rc* = *obj*.**nrows** *()* ;

Get the current row count from the OUTSELECT instance.

Parameters

There are no parameters associated with this method.

OUTSTAT Object Summary

DECLARE OBJECT obj(OUTSTAT) defines an object that is used to collect parameter estimates from a FORENG instance, print them, and store them. The CAS table schema used for storing the parameter estimates is compatible with that used by PROC HPFENGINE for its OUTSTAT= data set.

OUTSTAT Synopsis

Object declaration statement:

DECLARE OBJECT *obj* *(***OUTSTAT***)* ;

Method syntax:

rc = *obj*.**Collect** *(FORENGObj)* ;

Attributes summary:

rc = *obj*.**nrows** *()* ;

Table 1.52 summarizes the methods that are associated with the OUTSTAT Object.

Table 1.52 Methods of OUTSTAT Object

OUTSTAT Method	Description
Collect	Collect the parameter estimates from the FORENG instance *FORENGObj*.
nrows	Get the current row count from the OUTSTAT instance.

OUTSTAT Methods

OUTSTAT.Collect Method

Usage: *rc* = *obj*.**Collect** *(FORENGObj)* ;

Collect the parameter estimates from the FORENG instance *FORENGObj*.

Parameters

[in] *FORENGObj* The FORENG object instance to use as the source of time series model parameter estimates.

OUTSTAT Attributes

OUTSTAT.nrows Method

Usage: *rc* = *obj*.**nrows** *()* ;

Get the current row count from the OUTSTAT instance.

Parameters

There are no parameters associated with this method.

OUTFMSG Object Summary

DECLARE OBJECT obj(OUTFMSG) defines an object that is used to persist forecast model selection graph (FMSG) XML to a CAS table. OUTFMSG is a PROC TSMODEL collector object.

Table 1.53 Contents of the OUTFMSG Object

Column	Type	Description
NAME	String	Name of the dependent variable (can be missing)
SPECNAME	Numeric	Name of the FMSG specification
SPECLEN	Numeric	Length of the XML specification for FMSG

Table 1.53 *continued*

Column	Type	Description
FMSGPEC	String	FMSG specification XML document

OUTFMSG Synopsis

Object declaration statement:

DECLARE OBJECT *obj* (**OUTFMSG**) **;**

Method syntax:

rc **=** *obj***.Collect** *(SourceObject)* **;**

Attributes summary:

rc **=** *obj***.nrows** *()* **;**

Table 1.54 summarizes the methods that are associated with the OUTFMSG Object.

Table 1.54 Methods of the OUTFMSG Object

OUTFMSG Method	Description
Collect	Collect forecast model selection graph for output to a CAS table
nrows	Query OUTFMSG object for its current row count

OUTFMSG Methods

OUTFMSG.Collect Method

Usage: *rc* **=** *obj***.Collect** *(SourceObject)* **;**

Collect forecast model selection graph for output to a CAS table.

Parameters

[in] *SourceObject* The instance to be used as the source of the diagnostic control option specification to be persisted.

Table 1.55 Allowed Arguments for *SourceObject*

SourceObject	**Description**
SELSPEC	FMSG XML generated from specification object content
DIAGNOSE	FMSG XML generated from DIAGNOSE object model XML
FORENG	FMSG XML generated from FORENG FMSG that is used to forecast

OUTFMSG Attributes

OUTFMSG.nrows Method

Usage: *rc* = *obj*.**nrows** *()* **;**

Query OUTFMSG object for its current row count.

Parameters

There are no parameters associated with this method.

INDIAG Object Summary

DECLARE OBJECT obj(INDIAG) defines a repeater object that is used to replay diagnostic control specifications that have been persisted to a CAS table via the OUTDIAG collector object.

INDIAG Synopsis

Object declaration statement:

DECLARE OBJECT *obj (***INDIAG***)* **;**

Attributes summary:

rc = *obj*.**nrows** *()* **;**

Table 1.56 summarizes the methods that are associated with the INDIAG Object.

Table 1.56 Methods of the INDIAG Object

INDIAG Method	**Description**
nrows	Query INDIAG object for its current row count

INDIAG Attributes

INDIAG.nrows Method

Usage: *rc* = *obj*.**nrows** *()* ;

Query INDIAG object for its current row count.

Parameters

There are no parameters associated with this method.

INFMSG Object Summary

DECLARE OBJECT obj(INFMSG) defines a repeater object that is used to replay forecast model selection graph (FMSG) XML specifications from a CAS table for use in a FORENG instance.

INFMSG Synopsis

Object declaration statement:

DECLARE OBJECT *obj (***INFMSG***)* ;

Attributes summary:

rc = *obj*.**nrows** *()* ;

Table 1.57 summarizes the methods that are associated with the INFMSG Object.

Table 1.57 Methods of the INFMSG Object

INFMSG Method	Description
nrows	Return the number of rows in the INFMSG object. A returned missing value indicates that the INFMSG object has not been successfully configured

INFMSG Attributes

INFMSG.nrows Method

Usage: *rc* = *obj*.**nrows** *()* ;

Return the number of rows in the INFMSG object. A returned missing value indicates that the INFMSG object has not been successfully configured.

Parameters

There are no parameters associated with this method.

INEST Object Summary

DECLARE OBJECT obj(INEST) defines a repeater object that is used to replay parameter estimates from CAS table for use in a FORENG instance.

INEST Synopsis

Object declaration statement:

DECLARE OBJECT *obj* (**INEST**) **;**

Attributes summary:

rc **=** *obj***.nrows** *()* **;**

Table 1.58 summarizes the methods that are associated with the INEST object.

Table 1.58 Methods of the INESTObject

INESTMethod	Description
nrows	Return the number of rows in the INEST object. A returned missing value indicates that the INEST object has not been successfully configured.

INEST Attributes

INEST.nrows Method

Usage: *rc* **=** *obj***.nrows** *()* **;**

Return the number of rows in the INESTobject. A returned missing value indicates that the INESTobject has not been successfully configured.

Parameters

There are no parameters associated with this method.

Examples: ATSM Package

Throughout this section, it is assumed that you have already started a CAS session and that the data tables that are used in this section are in mycas, a CAS library that you have necessary permissions to work with. In all the examples of this section, the functionality of the TSM package is illustrated using the TSMODEL procedure. This section assumes that you are familiar with the general workings of the TSMODEL procedure; for more information, see Chapter 2, "The TSMODEL Procedure" (*SAS Visual Forecasting: Forecasting Procedures*).

Example 1.1: Automatic Modeling and Forecasting of the Airline Series

The airline passenger data, given as Series G in Box and Jenkins (1976), have been used in time series analysis literature as an example of a nonstationary seasonal time series; for more information about ARIMA modeling of Series G, see "Example 7.2 Seasonal Model for the Airline Series" in the ARIMA chapter of *SAS/ETS User's Guide*.

This example shows how you can use the objects in the ATSM package to automatically model the airline series. There is no one best way to do this. You can customize your modeling choices by appropriately configuring the DIAGSPEC and DIAGNOSE objects. After that, you use a FORENG object to produce the analysis results based on the diagnostic choices that you have made for the DIAGNOSE object. The main steps in the program are as follows:

1. The PROC TSMODEL statement specifies the input data set (mycas.air) and a variety of output tables (mycas.airFor, mycas.airEst, and so on).
2. The ID statement specifies date as the time index variable, and the INTERVAL= option indicates that the data are monthly.
3. The VAR statement specifies the input data set variable, air, which contains the airline series.
4. The REQUIRE statement specifies the ATSM package, which is needed for the analysis.
5. The statements between the SUBMIT and ENDSUBMIT statements use the ATSM package objects to perform the actual analysis in your CAS session. These statements are grouped into four parts:
   - The first part creates a data frame, airData, which is a TSDF object that contains the necessary analysis variables. The variable roles—for example, whether target or input—and the default season length that is associated with the data frame are also assigned in this step.
   - In the second part, the model identification process is specified. This is done in two steps. First a DIAGSPEC object, airDiagSpec, is configured. It is then used to initialize a DIAGNOSE object, airDiag. The DIAGSPEC object in this example uses the default settings, which amounts to selecting the best fitting model from two model families: exponential smoothing models (ESMs) and ARIMAX models. As a result of setting the HOLDOUT parameter for the DIAGNOSE object to 12, the best fitting model is chosen within each family on the basis of the RMSE criterion (the default CRITERION choice) in the holdout region (the last 12 observations).

- In the third part, a FORENG object is used to do the final model selection and to produce forecasts. This FORENG object, airEng, is initialized by using the airDiag object that is created in the second part.
- In the last part, various output tables are created by using the collector objects of appropriate type.

```
proc tsmodel data=mycas.air
    outobj=(airFor=mycas.airFor airEst=mycas.airEst
       modInfo=mycas.modInfo airSelect=mycas.airSelect);
    id date interval=month;
    var air;
    require atsm;
    submit;

       declare object airData(tsdf);
       rc = airData.Initialize();
       rc = airData.AddY(air);
       rc = airData.SetOption('seasonality', 12);

       declare object airDiagSpec(diagspec);
       rc = airDiagSpec.Open();
       rc = airDiagSpec.SetESM();
       rc = airDiagSpec.SetARIMAX();
       rc = airDiagSpec.Close();
       declare object airDiag(diagnose);
       rc = airDiag.Initialize(airData);
       rc = airDiag.SetSpec(airDiagSpec);
       rc = airDiag.SetOption('holdout', 12);
       rc = airDiag.Run();

       declare object airEng(foreng);
       rc = airEng.Initialize(airDiag);
       rc = airEng.SetOption('lead', 12);
       rc = airEng.Run();

       declare object modInfo(outmodelinfo);
       rc = modInfo.Collect(airEng);
       declare object airFor(outfor);
       rc = airFor.Collect(airEng);
       declare object airEst(outest);
       rc = airEst.Collect(airEng);
       declare object airSelect(outselect);
       rc = airSelect.Collect(airEng);

    endsubmit;
quit;
```

Output 1.1.1 shows the results of final model selection step, Output 1.1.2 shows the parameter estimates of the selected model, and Output 1.1.3 shows the forecasts according to the selected model:

Output 1.1.1 Information about the Selected Model (Partial Output)

Choice Between the ESM and ARIMA Models

MODEL	_SELECTED_	_LABEL_
ARIMAX	NO	ARIMA: AIR ~ P = 1 D = (1,12) NOINT
ESM	YES	Winters Method (Multiplicative)

Output 1.1.2 Parameter Estimates of the Selected Model (Partial Output)

Parameter Estimates for the Multiplicative Winters Model

COMPONENT	_EST_	_STDERR_	_TVALUE_	_PVALUE_
LEVEL	0.3073	0.0315	9.7448	1.8E-17
TREND	0.00100	0.00302	0.3307	0.7413
SEASON	0.8749	0.0777	11.2612	2.2E-21

Output 1.1.3 Forecasts Based on the Selected Model (Partial Output)

Forecasts Based On the Multiplicative Winters Model

DATE	PREDICT	STD	UPPER	LOWER
01JAN61	445.3	10.6910	466.3	424.3
01FEB61	418.1	11.1235	439.9	396.3
01MAR61	464.1	11.7900	487.2	441.0
01APR61	494.0	12.4171	518.4	469.7
01MAY61	505.0	12.9152	530.3	479.6
01JUN61	572.6	13.9646	600.0	545.2
01JUL61	662.7	15.3576	692.8	632.6
01AUG61	653.8	15.5579	684.3	623.3
01SEP61	545.9	14.4949	574.3	517.5
01OCT61	487.7	14.0959	515.3	460.1
01NOV61	415.3	13.5185	441.8	388.8
01DEC61	459.6	14.5119	488.0	431.2

References

Box, G. E. P., and Jenkins, G. M. (1976). *Time Series Analysis: Forecasting and Control*. Rev. ed. San Francisco: Holden-Day.

Chapter 2

Simple Forecast Service Package for the TSMODEL Procedure

Contents

Overview

This chapter describes the simple forecast service (SFS) package that can be used with the TSMODEL procedure. The SFS package provides a simple-to-use interface for automatically forecasting services for univariate time series. The SFS package implements a set of best-practice rules to define its behavior and uses the same underlying forecasting software as SAS Forecast Server and SAS Visual Analytics time series forecasting. It is called “simple” because only a few options are needed to control its behavior. More sophisticated time series forecasting services are available in other time series packages that are described in this book. If you want to exercise more control over the forecasting process, use one of those packages.

The SFS package is object-oriented (OO). To use the SFS package, you must declare instances of the object classes that are contained in the package. Declaring an object instance is the OO equivalent of declaring a program variable. As with simple program variables, the declaration assigns the instance a name of your choosing and a type, which is defined by the object’s class. Unlike simple program variables, the object instance requires a different syntax for interacting with it and offers different functions (methods) that are contextual to the object. Object instances hold information (data and results) over the lifetime of the instance. From a programming perspective, this property makes them very different from a function call, which generally is idempotent (a function operates on inputs and produces outputs that have no carryover effects from one call to the next). The object can offer very sophisticated capabilities with a simple-to-use interface.

SFS Package Summary

Table 2.1 summarizes the single object class that is contained in the SFS package.

Table 2.1 Classes in the SFS Package

SFS Function	Description
SFS	Automatically model and forecast univariate time series.

Common Argument Types

Table 2.2 defines the common argument types that are used in this chapter.

Table 2.2 Common Argument Types

SAS Data Type	Declaration Syntax
String	LENGTH *x* **$***n***;**
Numeric	*x* or LENGTH *x 8***;**
Numeric array	ARRAY *x***[***n***]**/NOSYMBOLS**;**
Status	*x* or LENGTH *x 8***;**

Status Code Convention

Table 2.3 shows the return code (rc) values that are used by all objects in this chapter.

Table 2.3 Status Codes

rc Value	Meaning
< 0	An unrecoverable error occurred. No result was produced.
= 0	Unconditional success. Requested action completed and normal result produced.
> 0	Conditional success or warning. A result was produced subject to conditions.

Upon returning a negative status code, most methods in the SFS package objects also write a message to the output log that explains the causes of the related failure. These messages provide extremely useful information during the process of debugging a user program. In the TSMODEL procedure, the output log is stored in the CAS table that is specified in the OUTLOG= option in the PROC TSMODEL statement. For more information about how to enable and configure logging and about how to access the output log after an invocation of the TSMODEL procedure, see Chapter 2, “The TSMODEL Procedure” (*SAS Visual Forecasting: Forecasting Procedures*).

SFS Object Summary

The SFS object is used to automatically model and forecast univariate time series. SFS capabilities range from automatic exponential smoothing (auto-ESM) to automatic model generation and automatic forecasting. The behavior of the SFS instance is dynamic depending on whether independent variables (predictors) are included for consideration. When only a dependent variable (a Y series) is included, the SFS instance generates an auto-ESM forecast by selecting from among the possible ESM methods as a function of whether the Y series is seasonal or not. When independent variables are included, automatic model generation is performed by the use of two autoregressive integrated moving average with explanatory variable (ARIMAX) identification techniques, in addition to an auto-ESM model. As many as three candidate models might be generated. The candidate models are then evaluated for their in-sample Bayesian information criterion (SBC) fit statistic, and the best performing model is selected to forecast the dependent variable. If the selected model uses predictors, those predictor series are lead-extended by using auto-ESM methods to forecast their future values for use in generating the forecast of the dependent series.

SFS Synopsis

The object declaration statement creates a new object, *obj*, of type SFS:

DECLARE OBJECT *obj* (**SFS**) **;**

Each SFS object in your program is independently instantiated by the **`timeData`** action for each BY-group thread. Each SFS object in your program is automatically reset by the **`timeData`** action at the start and end of each BY group. Table 2.4 summarizes the methods that are associated with the SFS object.

Table 2.4 Methods of the SFS Object

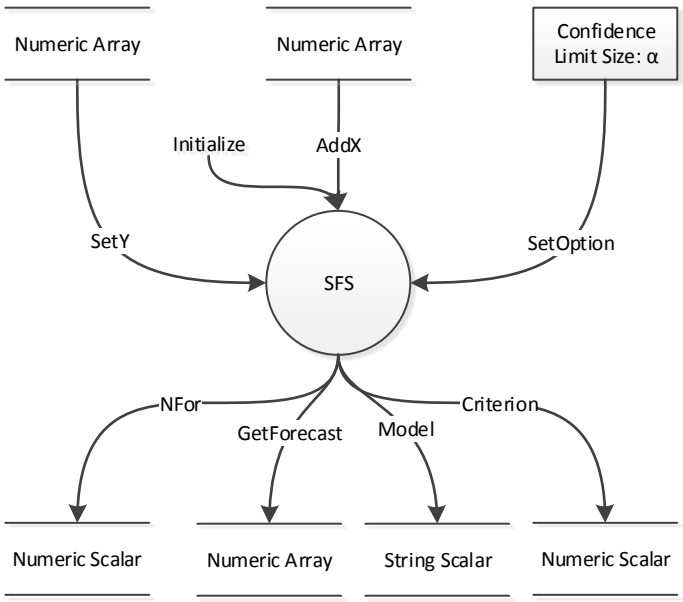
SFS Method	Description
Initialize	Initialize or reset the SFS object for use.
SetY	Specify the dependent time series.
AddX	Add an independent time series.
SetOption	Specify a computational option via a *Name*,*Value* pair.
Run	Automatically model and forecast the dependent variable.
GetForecast	Retrieve a computed forecast series by name.
nfor	Get the length (observation count) of the forecast series.
criterion	Get the in-sample Bayesian information criterion (SBC) fit statistic for the selected time series model.
model	Get the short name of the selected model that is used to produce the final forecast.

The SFS object has the following calling sequence protocol:

1. You must call SFS.Initialize() before calling any other SFS methods or attributes.
2. You must call SFS.SetY() before calling SFS.Run(). Each call to SFS.SetY() before calling SFS.Run() simply replaces the dependent series.
3. You can call SFS.AddX() zero or more times prior to SFS.Run(). Each SFS.AddX() call includes the specified independent series for consideration during model generation. Independent variables are tracked by the array name that you specify in the SFS.AddX() method call. Calling SFS.AddX() repeatedly with the same array name simply replaces the variable's series with the values from the most recent call.
4. You can call SFS.SetOption() prior to SFS.Run() to change mutable properties of the SFS instance. Mutable properties in effect at the time of the SFS.Run() call are used.
5. After a successful SFS.Run() call, you can call SFS.GetForecast() to retrieve the forecast series. Calls to SFS.GetForecast() before calling SFS.Run() or calls made after an unsuccessful SFS.Run() return missing values to your *Result* array.
6. After a successful SFS.Run, you can call the attribute methods to retrieve their respective values. Calls to the attribute methods before calling SFS.Run() or calls made after an unsuccessful SFS.Run() return missing values.

Figure 2.1 outlines the programmatic data flow through the SFS object; each arrow represents a different object method.

Figure 2.1 SFS Object Data Flow



SFS Methods

This section describes the methods of a SFS object.

SFS.Initialize Method

The Initialize method initializes or resets the SFS instance for use.

Usage: *rc* **=** *obj***.Initialize** *()* **;**

Parameters

There are no parameters associated with this method.

SFS.SetY Method

The SetY method specifies the dependent time series array (*YSeries*) for the SFS instance.

Usage: *rc* **=** *obj***.SetY** *(YSeries)* **;**

Parameters

[in] *YSeries* Numeric array used to specify the dependent series for the SFS instance.

SFS.AddX Method

The AddX method adds an independent time series array (*XSeries*) for the SFS instance.

Usage: *rc* **=** *obj***.AddX** *(XSeries)* **;**

Each call to the AddX method adds the specified independent variable to the SFS instance. This method can be called as many times as needed to specify all the independent variables that are needed for the time series model that is used to initialize the SFS instance.

Parameters

[in] *XSeries* Numeric array used to specify an independent series for the SFS instance.

SFS.SetOption Method

The SetOption method specifies computational options for the SFS instance as *Name*,*Value* pairs.

Usage: *rc* **=** *obj***.SetOption** *(Name, Value < , Name, Value,... >)* **;**

More than one *Name*,*Value* pair can be specified in a single call. *Name* is a character literal or variable. The type of *Value* depends on the value of *Name*. Table 2.5 shows the allowed options.

Table 2.5 Parameters for the SFS.SetOption Method

Name	Value Type	Description
ALPHA	Numeric	Significance level for confidence bands (0 < *Value* < 1)

Parameters

[in] *Name* Character literal or variable that names the option.

[in] *Value* Specifies the value for the named option.

SFS.Run Method

The Run method runs the SFS instance to automatically model and forecast the dependent variable.

Usage: *rc* **=** *obj*.**Run** *()* **;**

If any independent variables are specified, they are considered during model generation and are included in the candidate models if they are causal to forecast the behavior of the dependent variable. Upon successful completion, various results can be extracted from the SFS instance. Up to three candidate models are generated automatically and might include the models shown in Table 2.6.

Table 2.6 Models Generated by the SFS.Run Method

Model	Description
ESM	Exponential smoothing model
ARIMAX	ARIMA model generated by finding an ARIMA model for the error series first and then choosing significant inputs and events (ARIMA-REG order)
REGARIMA	ARIMA model generated by finding a regression model first and then deciding the autoregressive (AR) and moving average (MA) polynomial orders (REG-ARIMA order)

Automatic model selection and forecasting follows by considering the performance of the candidate models based on their in-sample performance as measured by their Bayesian information criterion (SBC) values. ARIMA candidate models are generated only when independent variables are included in the analysis.

Parameters

There are no parameters associated with this method.

SFS.GetForecast Method

The GetForecast method fetches the specified forecast series (*Which*) from the SFS instance and writes it into the specified numeric array (*Result*). *Which* is a case-insensitive character string.

Usage: *rc* = *obj*.**GetForecast** *(Which, Result)* **;**

Parameters

[in] *Which* Character literal or string whose value specifies the forecast series to return. Table 2.7 shows the series types that are supported.

Table 2.7 'Which' Parameters for the SFS.GetForecast Method

Which	Description
PREDICT	Forecast series
ERROR	Error series (forecast minus actual)
STDERR	Forecast standard error series
UPPER	Upper confidence limit series
LOWER	Lower confidence limit series

[out] *Result* Numeric array in which to write the forecast series. If the array length is longer than the forecast series, it is padded with missing values.

SFS.nfor Attribute

The nfor attribute returns the length (observation count) of the forecast series for the SFS instance.

Usage: *rc* = *obj*.**nfor** *()* **;**

A missing value indicates that the SFS object has not produced a successful forecast.

Parameters

There are no parameters associated with this method.

SFS.criterion Attribute

The criterion attribute returns the fit statistic value for the final forecast for the SFS instance.

Usage: *rc* = *obj*.**criterion** *()* **;**

The criterion is the in-sample Bayesian information criterion (SBC) fit statistic for the selected time series model. A missing value indicates that the SFS instance has not produced a successful forecast.

Parameters

There are no parameters associated with this method.

SFS.model Attribute

The model attribute returns the short name of the selected model that is used to produce the final forecast.

Usage: *rc* **=** *obj*.**model** *()* **;**

A missing value (null string) indicates that the SFS instance has not produced a successful forecast. Table 2.8 shows the possible returned values.

Table 2.8 Models Returned by the SFS.model Attribute

Model	Description
ESM	Exponential smoothing model
ARIMAX	ARIMA model generated by finding an ARIMA model for the error series first and then choosing significant inputs and events (ARIMA-REG order)
REGARIMA	ARIMA model generated by finding a regression model first and then deciding the autoregressive (AR) and moving average (MA) polynomial orders (REG-ARIMA order)

Parameters

There are no parameters associated with this method.

Examples: SFS Package for the TSMODEL Procedure

Example 2.1: Simple Forecasting

This example shows how you can use the SFS object to generate a forecast by automatic exponential smoothing (auto-ESM). This example uses the familiar Sashelp.Air data set, which is forecast at two different frequencies. The data are naturally recorded as monthly passenger counts. They are forecast at the monthly level and the quarterly level.

The following DATA step loads the Sashelp.Air data set onto the CAS server. This DATA step assumes that your CAS engine libref is named mycas, but you can substitute any appropriately defined CAS engine libref.

```
data mycas.Air (replace=yes);
   set Sashelp.Air;
run;
```

The following SAS code uses the TSMODEL procedure to submit the program that uses the SFS object. The REQUIRE statement loads the SFS package and installs its classes (SFS class) so that the program can use the package. Failure to include the REQUIIRE statement would produce compilation errors when the program is submitted to the **`timeData.runTimeCode`** action. Air is the dependent variable to be forecast. Because no ACCUMULATE= option is specified in the ID or VAR statements, its default value of TOTAL is used, which accumulates observations within a time period as a total sum of the nonmissing values. The OUTSCALAR statement declares that Nfor, Fitstat, and Rc are numeric variables to be stored in the CAS table mycas.Airmonos, which is specified in the OUTSCALAR= option in the PROC TSMODEL statement. The OUTARRAY statement declares the length-conformant numeric array Airmonfor, which is written to the CAS table mycas.Airmonoa, which is specified in the OUTARRAY= option in the PROC TSMODEL statement. You use the DECLARE OBJECT to define the SFS instance named **`esm`**. Method calls on the object instance use the dot notation. The calls **`esm.Initialize()`**, **`esm.SetY()`**, and so on are performed sequentially with a status check following each to ensure that the method call was successful. If any call fails, the program stops execution. Following a successful **`esm.Run()`** call, attributes and forecasts are fetched from the **`esm`** object.

```
proc tsmodel data=mycas.air
     outarray=mycas.airmonoa(replace=yes)
     outscalar=mycas.airmonos(replace=yes)
     lead=12;
id date interval=month;
var air;
outarray airmonfor;
outscalar nfor fitstat rc;
require sfs;
submit;
  declare object esm(sfs);

  rc = esm.Initialize();
  if rc < 0 then do;
     stop;
  end;

  rc = esm.SetY(air);
  if rc < 0 then do;
     stop;
  end;

  rc = esm.Run();
  if rc < 0 then do;
     stop;
  end;

  nfor = esm.nfor();
  fitstat = esm.criterion();

  rc = esm.GetForecast('predict',airmonfor);
  if rc < 0 then do;
     stop;
  end;
endsubmit;
quit;
```

When the **timeData** action runs the program that you submit from PROC TSMODEL, it generates a summary of the processing that is performed in your CAS session, as shown in Output 2.1.1.

Output 2.1.1 Summary of Time Series Processing for mycas.air

The TSMODEL Procedure

Summary of time series processing for AIR	
Number of analysis variables	1
Number of rows read	288
Number of groups read	1
Memory for group packages (KB)	10
Time to read groups (seconds)	0.0001170635
Time to load groups (seconds)	0.0006611347
Number of data threads	3
Thread BY group redundancy	3
Minimum time ID	JAN1949
Maximum time ID	DEC1960
Minimum time periods	144
Maximum time periods	144
Number of nodes run	1
Number of nodes with data	1
Number of nodes with groups	1
Number of threads budgeted	40
Minimum thread group count	1
Maximum thread group count	1
Minimum threads active	1
Maximum threads active	1
Average CPU utilization of nodes with data (%)	100
Minimum CPU utilization of nodes with data (%)	100
Maximum CPU utilization of nodes with data (%)	100
Number of groups processed by submitted code	1
Number of groups failing	0
Elapsed time to process groups (seconds)	0.0033090115
Number of array table rows produced	156
Number of scalar table rows produced	1

When this code runs, the **timeData.runTimeCode** action forms the monthly time series for the column Air from the CAS table mycas.Air using the time ID variable Date. The program uses the SFS object **esm** to create the best ESM model for this data and then uses that model to forecast for 12 months. The best ESM model is determined by a statistical assessment of some properties of the dependent series (for example, seasonality). Then suitable ESM candidate smoothing methods (for example, SIMPLE, TREND, and DAMPTREND methods for nonseasonal data and WINTERS and MULTWINTERS methods for seasonal data) are used to select the model that has the best in-sample root mean square error (RMSE) fit statistic. The forecast is queried from the **esm** instance into the array Airmonfor, which is then automatically saved to the CAS table mycas.Airmonoa by the use of the OUTARRAY statement and the OUTARRAY= option in the PROC TSMODEL statement. Scalar variables of interest from the execution of the program are also saved by the use of the OUTSCALAR statement and the OUTSCALAR= option in the PROC TSMODEL statement.

The following code prints the OUTSCALAR= table from the preceding **timeData** action call. The PROC PRINT results are shown in Output 2.1.2.

```
proc print data=mycas.airmonos; run;
```

Output 2.1.2 OUTSCALAR Table

Obs	_STATUS_	nfor	fitstat	rc
1	0	156	10.579085435	0

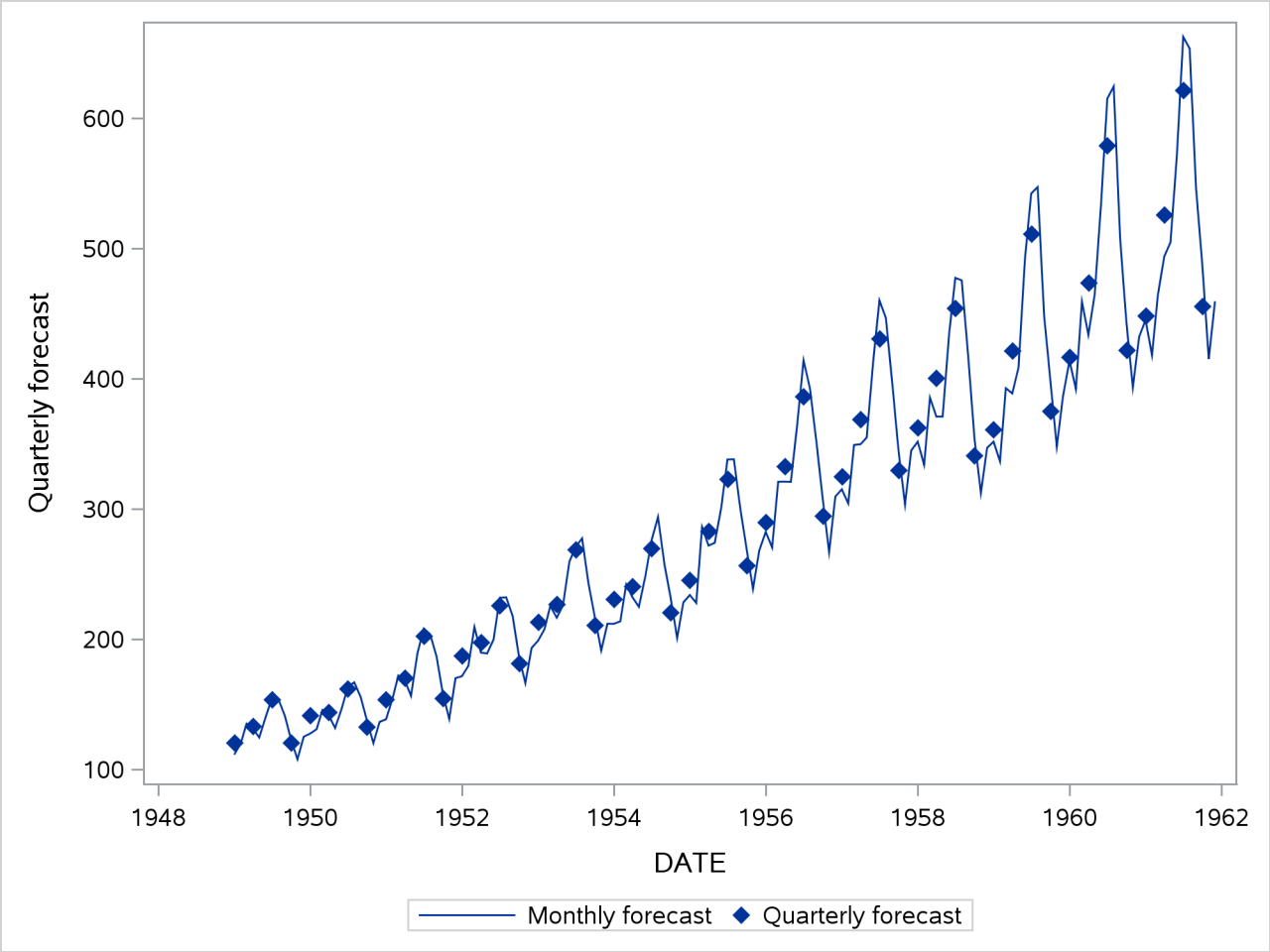
Suppose you want to forecast the quarterly average airline passenger data for a year into the future. The following simple modifications to the SAS code create the quarterly forecast for a four-quarter horizon:

```
proc tsmodel data=mycas.air
     outarray=mycas.airqtroa(replace=yes)
     outscalar=mycas.airqtros(replace=yes)
     lead=4;
id date interval=qtr;
var air/accumulate=avg;
outarray airqtrfor;
outscalar nfor fitstat rc;
require sfs;
submit;
  declare object esm(sfs);

  rc = esm.Initialize();
  if rc < 0 then do;
     stop;
  end;

  rc = esm.SetY(air);
  if rc < 0 then do;
     stop;
  end;

  rc = esm.Run();
  if rc < 0 then do;
     stop;
  end;

  nfor = esm.nfor();
  fitstat = esm.criterion();

  rc = esm.GetForecast('predict',airqtrfor);
  if rc < 0 then do;
     stop;
  end;
endsubmit;
quit;
```

The following SAS code demonstrates one of many ways that you might want to generate a plot of the two forecasts. This code uses the SGPLOT procedure to display the monthly forecasts as a time series and to overlay the quarterly forecasts as a scatter plot. The PROC SGPLOT results are shown in Output 2.1.3.

```
data airboth;
  label airmonfor='Monthly forecast';
  label airqtrfor='Quarterly forecast';
  merge mycas.airmonoa
        mycas.airqtroa;
  by date;
run;

proc sgplot data=airboth;
  series x=date y=airmonfor;
  scatter x=date y=airqtrfor/markerattrs=(symbol=DiamondFilled);
run;
```

Output 2.1.3 Monthly and Quarterly Airline Passenger Forecasts



Example 2.2: Automatic Forecasting Using Predictor Series

This example shows how you can use the SFS object to automatically model and forecast time series data that include the use of predictor series. The following DATA step loads the Sashelp.Pricedata data set onto the CAS server. This DATA step assumes that your CAS engine libref is named mycas, but you can substitute any appropriately defined CAS engine libref.

```
data mycas.Pricedata (replace=yes);
   set Sashelp.Pricedata;
run;
```

The example forecasts unit sales (Sale) over the BY groups that are defined by the distinct products (ProductName), considering possible predictor series for price and discount. However, it forecasts sales by using the relative sales series (Relsale) as the dependent variable and relative price (Relprice) as a candidate predictor in place of the accumulated Sale and Price series. The example then rescales the Relsale forecasts back to the original domain for generating a sales forecast. For this particular example, there is no compelling reason to forecast in the domain of the indexed (relative) series, but it demonstrates the power of the **timeData** action's programming approach to devise custom treatments of time series processing problems that can be realized in a single pass of the data. Such techniques allow for combining custom programming logic with the power of the SFS object to perform sophisticated automatic forecasting.

```
proc tsmodel data=mycas.pricedata
     outarray=mycas.saleoa(replace=yes)
     outscalar=mycas.saleos(replace=yes)
     lead=12;
by productName;
id date interval=month start='01jan1998'd end='01dec2002'd;
var sale /accumulate=sum;
var price discount /accumulate=avg;
outarray relsale relprice predict;
outscalar sbase pbase nfor fitstat rc model $32;
require sfs;
submit;
  declare object lasr(sfs);
  sbase=sale[1];
  pbase=price[1];
  do i=1 to _length_;
    if sale[i] ne . then do;
      relsale[i] = sale[i]/sbase;
    end;
    if price[i] ne . then do;
      relprice[i]=price[i]/pbase;
    end;
  end;

  rc = lasr.Initialize();
  if rc < 0 then do;
     stop;
  end;

  rc = lasr.SetY(relsale);
  if rc < 0 then do;
```

```
      stop;
   end;

   rc = lasr.AddX(relprice);
   if rc < 0 then do;
      stop;
   end;

   rc = lasr.AddX(discount);
   if rc < 0 then do;
      stop;
   end;

   rc = lasr.Run();
   if rc < 0 then do;
      stop;
   end;

   nfor = lasr.nfor();
   fitstat = lasr.criterion();
   model = lasr.model();

   rc = lasr.GetForecast('predict',predict);
   if rc < 0 then do;
      stop;
   end;

   do i=1 to _length_;
     predict[i] = predict[i]*sbase;
   end;
 endsubmit;
 quit;
```

When the **timeData** action runs the program that you submit from PROC TSMODEL, it generates a summary of the processing that is performed in your CAS session, as shown in Output 2.2.1.

Output 2.2.1 Summary of Time Series Processing for mycas.pricedata

The TSMODEL Procedure

Summary of time series processing for PRICEDATA	
Number of analysis variables	3
Number of rows read	1020
Number of groups read	17
Memory for group packages (KB)	102
Time to read groups (seconds)	0.0005130768
Time to load groups (seconds)	0.0011470318
Number of data threads	3
Thread BY group redundancy	1.0588235294
Minimum time ID	JAN1998
Maximum time ID	DEC2002
Minimum time periods	60
Maximum time periods	60
Number of nodes run	1
Number of nodes with data	1
Number of nodes with groups	1
Number of threads budgeted	40
Minimum thread group count	1
Maximum thread group count	1
Minimum threads active	1
Maximum threads active	17
Average CPU utilization of nodes with data (%)	50.25
Minimum CPU utilization of nodes with data (%)	50.25
Maximum CPU utilization of nodes with data (%)	50.25
Number of groups processed by submitted code	17
Number of groups failing	0
Elapsed time to process groups (seconds)	0.0262799263
Number of array table rows produced	1224
Number of scalar table rows produced	17

The following SAS code prints the table that is specified in the OUTSCALAR= option in the PROC TSMODEL statement. The OUTSCALAR= table includes several variables that were captured from the program execution for each BY group in the Pricedata table. The PROC PRINT results are shown in Output 2.2.2.

```
proc print data=mycas.saleos; run;
```

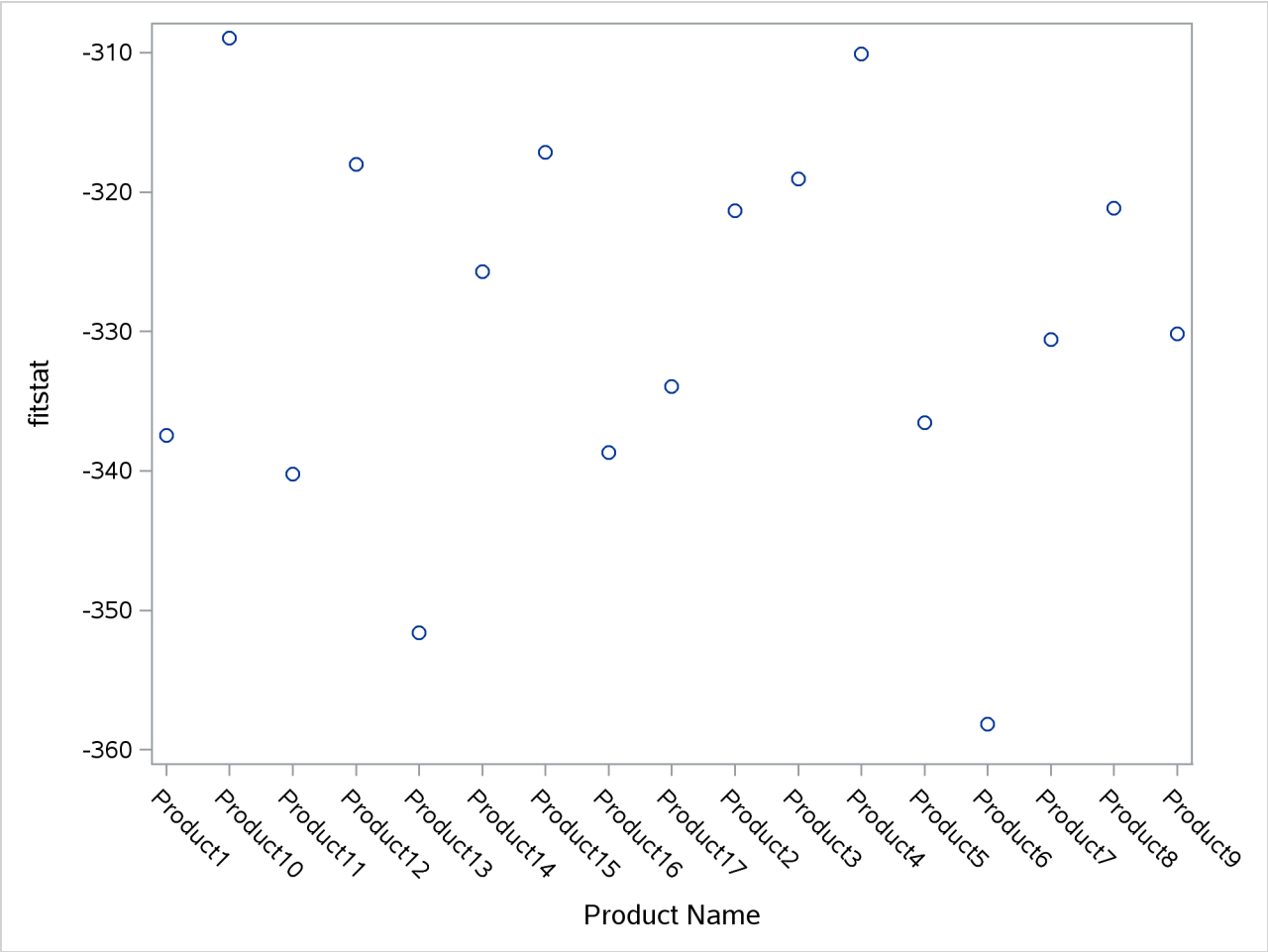
Output 2.2.2 OUTSCALAR Table

Obs	productName	_STATUS_	sbase	pbase	nfor	fitstat	rc	model
1	Product1	0	355	52.3	72	-337.4629078	0	REGARIMA
2	Product10	0	329	59	72	-308.9521995	0	REGARIMA
3	Product11	0	240	65.2	72	-340.2472948	0	REGARIMA
4	Product12	0	413	147	72	-318.0312143	0	REGARIMA
5	Product13	0	359	122	72	-351.6217156	0	REGARIMA
6	Product14	0	462	53	72	-325.7278047	0	REGARIMA
7	Product15	0	383	120.2	72	-317.1505661	0	REGARIMA
8	Product16	0	491	70.55	72	-338.6653664	0	REGARIMA
9	Product17	0	359	80.5	72	-333.9525131	0	REGARIMA
10	Product2	0	373	115	72	-321.3360261	0	REGARIMA
11	Product3	0	300	33.4	72	-319.0745186	0	REGARIMA
12	Product4	0	418	67.9	72	-310.1082484	0	REGARIMA
13	Product5	0	416	36	72	-336.5399506	0	REGARIMA
14	Product6	0	550	38.88	72	-358.1769437	0	REGARIMA
15	Product7	0	435	42	72	-330.6016099	0	REGARIMA
16	Product8	0	404	56.9	72	-321.1618287	0	REGARIMA
17	Product9	0	461	171.4	72	-330.1588485	0	REGARIMA

The following SAS code generates a scatter plot of the fit statistics for the various product groups on a single graph. Note that the X-axis ordering of ProductName values is forced to be the collating sequence by using the result of the PROC SORT step, whereas the order from the preceding PROC PRINT step is the natural order that is returned from the CAS table. When processing results are generated as output tables from CAS actions, it is often necessary to sort them in order to create a desired row set ordering. The PROC SGPLOT results are shown in Output 2.2.3.

```
proc sort data=mycas.saleos out=saleos;
  by productName;
run;
proc sgplot data=saleos;
  scatter x=productName y=fitstat;
run;
```

Output 2.2.3 Fit statistics by Product



Example 2.3: Using SFS with PROC CAS

This example shows how you can use the SFS object with the CAS procedure to call the **timeData.runTimeCode** action. This example uses the same Sashelp.Pricedata data set as is used in Example 2.2. This example uses the auto-ESM mode of the SFS object to generate forecasts and confidence bands for average sales by region (Region).

The following SAS code shows how you can use PROC CAS to submit the program that uses the SFS object. Unlike PROC TSMODEL, PROC CAS does not have custom syntax and statements for the **timeData.runTimeCode** action. To use PROC CAS to call a CAS action, you must form the CAS action's call as it is defined in the CAS action set. For more information about the **timeData** action set, see *SAS Visual Forecasting: Programming Guide*. For more information about PROC CAS, see *SAS Cloud Analytic Services: CAS Procedure Programming Guide and Reference*. Even without detailed documentation, you can see the connections between the **timeData.runTimeCode** action's arguments and the options and statements that are used in Example 2.2, which uses the TSMODEL procedure.

```
%macro cmpcode(yvar,pred,ucl,lcl);
 declare object esm(sfs);
 rc = esm.initialize();
 if rc < 0 then do;
    stop;
 end;
 rc = esm.sety(&yvar);
 if rc < 0 then do;
    stop;
 end;
 rc = esm.run();
 if rc < 0 then do;
    stop;
 end;
 nfor = esm.nfor();
 fitstat = esm.criterion();
 rc = esm.getForecast('predict',&pred);
 if rc < 0 then do;
    stop;
 end;
 rc = esm.getForecast('upper',&ucl);
 if rc < 0 then do;
    stop;
 end;
 rc = esm.getForecast('lower',&lcl);
 if rc < 0 then do;
    stop;
 end;
%mend;

proc cas;
  cmpcode="%cmpcode(sale,sale_for,sale_ucl,sale_lcl)";
  session casref=mycas; run;
  timeData.runTimeCode /
     table={name="pricedata"
            groupby={"region"}
```

```
      }
      require={{pkg="sfs"}}
      series={{name="sale" acc="sum"}}
      timeid="date"
      interval="month"
      arrayOut={table={name="csaleoa" replace=true}
                arrays={"sale_for" "sale_ucl" "sale_lcl"}
      }
      scalarOut={table={name="csaleos" replace=true}
                 scalars={"rc" "nfor" "fitstat"}
      }
      lead=12
      code=cmpcode;
    run;
  quit;
```

When the **timeData** action runs the program that you submit from PROC CAS, it generates a summary of the processing that is performed by your CAS session. That summary is shown in Output 2.3.1.

Output 2.3.1 Summary of Time Series Processing for mycas.pricedata

Results from timeData.runTimeCode

Summary of time series processing for PRICEDATA	
Number of analysis variables	1
Number of rows read	2040
Number of groups read	3
Memory for group packages (KB)	8
Time to read groups (seconds)	0.0043582916
Time to load groups (seconds)	0.0050089359
Number of data threads	3
Thread BY group redundancy	1.3333333333
Minimum time ID	JAN1998
Maximum time ID	DEC2002
Minimum time periods	60
Maximum time periods	60
Number of nodes run	1
Number of nodes with data	1
Number of nodes with groups	1
Number of threads budgeted	40
Minimum thread group count	1
Maximum thread group count	1
Minimum threads active	1
Maximum threads active	3
Average CPU utilization of nodes with data (%)	100
Minimum CPU utilization of nodes with data (%)	100
Maximum CPU utilization of nodes with data (%)	100
Number of groups processed by submitted code	3
Number of groups failing	0
Elapsed time to process groups (seconds)	0.0039379597
Number of array table rows produced	216
Number of scalar table rows produced	3

The following SAS code generates a series plot of the forecasts and confidence limits for region 1.

```
data csaleoa;
   set mycas.csaleoa;
run;
proc sort data=csaleoa;
  by region date;
run;
proc sgplot data=csaleoa(where=(region=1));
  band x=date upper=sale_ucl lower=sale_lcl;
  series x=date y=sale_for;
  scatter x=date y=sale;
run;
```

PROC SGPLOT results are shown in Output 2.3.2

Output 2.3.2 Sales Forecasts for Region 1

Chapter 3
Time-Frequency Analysis Package for the TSMODEL Procedure

Contents

Overview

Time-frequency analysis refers to techniques that analyze a time series in both time and frequency domains. The time-frequency analysis (TFA) package provides objects (organized in classes) that enable you to perform time-frequency analysis as part of the programming statements in the TSMODEL procedure in SAS Visual Forecasting.

TFA Package Summary

Table 3.1 summarizes the classes in the TFA package.

Table 3.1 Classes in the Time-Frequency Analysis Package

TFA Class	Description
FFT	Computes the discrete Fourier transform of a real time series
FFTC	Computes the discrete Fourier transform of a complex time series
HILBERT	Computes the analytic signal that corresponds to a real time series
PWV	Computes the pseudo-Wigner-Ville distribution of a real time series
STFT	Computes the short-time Fourier transform of a real time series
WINDOW	Creates a window of a requested type and length

TFA classes can be run independently for each BY group by specifying the BY statement. It is necessary in most cases to also add the TRIMID=BOTH option in the ID statement. For an example, see the section "Example" on page 80.

FFT Class

DECLARE OBJECT *f* **(FFT) ;**

DECLARE OBJECT *of* **(OUTFFT) ;**

rc **=** *f***.Run** *('Name','Value['Name','Value,...])* **;**

rc **=** *of***.Collect** *(f)* **;**

The FFT class computes the discrete Fourier transform of a real time series. Given an input array $y = \begin{pmatrix} y[0] & y[1] & \dots & y[n-1] \end{pmatrix}$ and $s = \pm 1$, the output is $z = \begin{pmatrix} z[0] & z[1] & \dots & z[n-1] \end{pmatrix}$, where

$$z[t] = \sum_{k=0}^{n-1} y[k] \exp \frac{s 2\pi \mathbf{i}\, k t}{n},\ 0 \le t \le n-1$$

When $s = -1$, the output z is the *forward* discrete Fourier transform of y; when $s = 1$, the output z is the *backward* discrete Fourier transform of y.

FFT Object

DECLARE OBJECT obj(FFT) defines an object that is used to compute the discrete Fourier transform of a real time series.

FFT.Run Method

Usage: *rc* **=** *obj***.Run** *('y','Value['sign','Value])* **;**

Required Arguments

You must specify the following argument as a '*Name*', *Value* pair:

y specifies an array of real-valued time series. Any missing value in this array is replaced by 0 before computation.

Optional Arguments

You can also specify the following argument as a '*Name*', *Value* pair:

sign specifies the sign of discrete Fourier transform. You can specify the following values within single or double quotation marks:

'FORWARD' calculates a forward discrete Fourier transform ($s = -1$).

'BACKWARD' calculates backward discrete Fourier transform with ($s = 1$).

The default value of *sign* is FORWARD. Forward and backward transforms are inverses to each other in the following sense: performing a backward transform on a time series of length n followed by a forward transform on the resulting series leads to n times the original series and vice-versa.

OUTFFT Object

DECLARE OBJECT obj(OUTFFT) defines an object that is used to collect output from FFT instance.

OUTFFT.Collect Method

Usage: *rc* **=** *obj*.**Collect** *('FFTObj')* **;**

This method collects the output of discrete Fourier transform from an FFT object and saves the result to a CAS table, whose schema is shown in Table 3.2.

Table 3.2 CAS Table Collected with OUTFFT

Column	Type	Description
X	Numeric	The real part of the discrete Fourier transform of input time series
Y	Numeric	The imaginary part of the discrete Fourier transform of input time series

OUTFFT.Nrows Attribute

Usage: *nrows* **=** *obj*.**nrows** *()* **;**

This attribute gets the current row count from the OUTFFT instance.

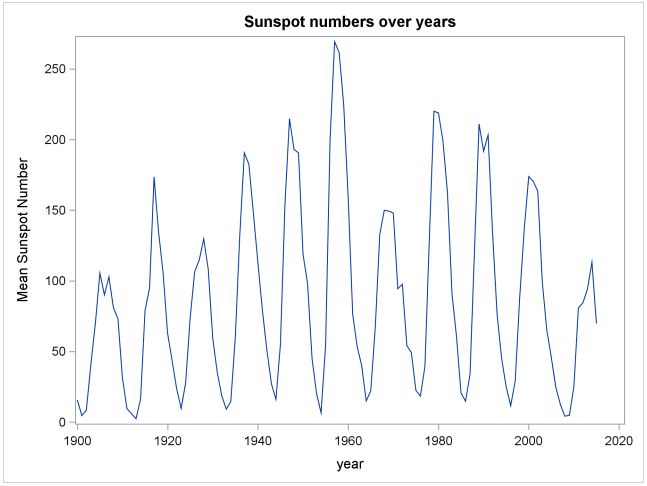
Example

The following statements read and plot the yearly sunspot count data since 1900. These statements assume that your CAS engine libref is named mycas, but you can substitute any appropriately defined CAS engine libref.

```
data mycas.sunspot;
   input x@@;
   year = _N_ + 1900 - 1;
   i = _N_;
   datalines;
15.7 4.6 8.5 40.8 70.1 105.5 90.1 102.8 80.9 73.2 30.9 9.5 6.0 2.4
16.1 79.0 95.0 173.6 134.6 105.7 62.7 43.5 23.7 9.7 27.9 74.0 106.5
114.7 129.7 108.2 59.4 35.1 18.6 9.2 14.6 60.2 132.8 190.6 182.6
148.0 113.0 79.2 50.8 27.1 16.1 55.3 154.3 214.7 193.0 190.7 118.9
98.3 45.0 20.1 6.6 54.2 200.7 269.3 261.7 225.1 159.0 76.4 53.4 39.9
15.0 22.0 66.8 132.9 150.0 149.4 148.0 94.4 97.6 54.1 49.2 22.5 18.4
39.3 131.0 220.1 218.9 198.9 162.4 91.0 60.5 20.6 14.8 33.9 123.0
211.1 191.8 203.3 133.0 76.1 44.9 25.1 11.6 28.9 88.3 136.3 173.9
170.4 163.6 99.3 65.3 45.8 24.7 12.6 4.2 4.8 24.9 80.8 84.5 94.0
113.3 69.8
;

proc sgplot data=mycas.sunspot;
   yaxis label="Mean Sunspot Number";
   title "Sunspot numbers over years";
   series x=Year y=x;
run;
```

Output 3.1 shows the results.

Figure 3.1 Sunspot Numbers over Years



The following statements call the FFT class to compute the forward discrete Fourier transform of the sunspot count data and store the result in the mycas.fft_x data set:

```
proc tsmodel data=mycas.sunspot outobj=(of=mycas.fft_x(replace=YES));
   var x;
   id i interval=second;
   require tfa;
   submit;
   declare object f(FFT);
```

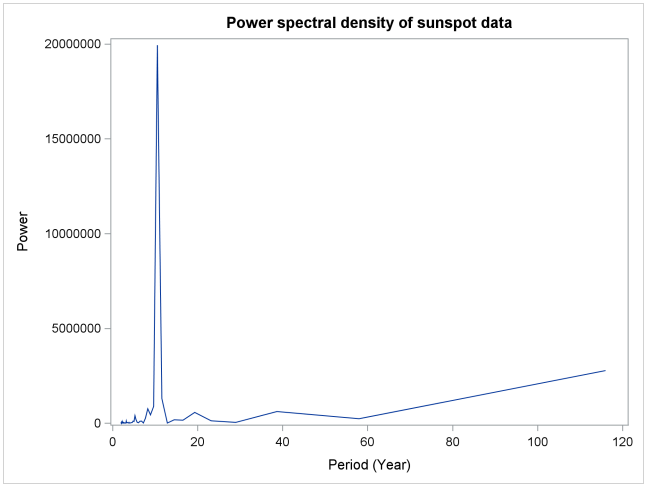
```
   declare object of(OUTFFT);
   rc = f.Run("Y", x); if rc then stop;
   rc = of.Collect(f); if rc then stop;
   endsubmit;
run;
```

The following statements plot the power spectral density. You can see a spike around 10 years.

```
data mycas.power;
   keep Freq Period Power;
   set mycas.fft_x nobs=n;
   Power = x ** 2 + y ** 2;
   Freq = (_n_-1)/n; /* Unit Hz */
   if Freq > 0;
   Period = 1/Freq;
   output;
   if Freq > 0.5 then stop;
run;

proc sgplot data=mycas.power;
   title "Power spectral density of sunspot data";
   xaxis label="Period (Year)";
   series x=Period y=Power;
run;
```

Output 3.2 shows the results.

Figure 3.2 Power Spectral Density of Sunspot Data



The following example runs the FFT class on column x of the mycas.x table. The BY statement causes the FFT class to be run on both group 1 (g=1) and group 2 (g=2):

```
data x;
   input x g;
   datalines;
   1  1
   2  1
   3  1
   4  1
```

```
  -3  2
   1  2
   3  2
   4  2
   0  2
   ;

data mycas.x;
   set x;
   i = _N_;
run;


proc tsmodel data=mycas.x outobj=(of=mycas.z(replace=YES));
   var x;
   by g;
   id i interval=second trimid=both;
   require tfa;
   submit;
   declare object f(FFT);
   declare object of(OUTFFT);
   /* Call FFT on x column of SAS table mycas.x */
   rc = f.Run("y", x, "sign", 'forward'); if rc then stop;
   rc = of.Collect(f); if rc then stop;
   endsubmit;
run;
```

FFTC Class

DECLARE OBJECT *f* **(FFTC)** **;**

DECLARE OBJECT *of* **(OUTFFTC)** **;**

rc **=** *f***.Run** *('Name',Value['Name',Value,...])* **;**

rc **=** *of***.Collect** *(f)* **;**

The FFTC class computes the discrete Fourier transform of a complex time series. Given an input array $y = \begin{pmatrix} y[0] & y[1] & \ldots & y[n-1] \end{pmatrix}$ and $s = \pm 1$, the output is $z = \begin{pmatrix} z[0] & z[1] & \ldots & z[n-1] \end{pmatrix}$, where

$$z[t] = \sum_{k=0}^{n-1} y[k] \exp \frac{s 2\pi \mathbf{i}\, k t}{n},\ 0 \le t \le n-1$$

When $s = -1$, the output z is the *forward* discrete Fourier transform of y; when $s = 1$, the output z is the *backward* discrete Fourier transform of y.

FFTC Object

DECLARE OBJECT obj(FFTC) defines an object that is used to compute the discrete Fourier transform of a complex time series.

FFTC.Run Method

Usage: *rc* = *obj*.**Run** *('Name','Value['Name','Value,...])* **;**

Required Arguments

You must specify the following arguments as '*Name*', *Value* pairs and separated by a comma:

y_re specifies an array of the real part of the input complex time series. Any missing value in this array is replaced with 0 before computation.

y_im specifies an array of the imaginary part of the input complex time series. Any missing value in this array is replaced with 0 before computation.

Optional Arguments

You can also specify the following argument as a '*Name*', *Value* pair:

sign specifies the sign of the discrete Fourier transform. You can specify the following values within single or double quotation marks:

'FORWARD' calculates a forward discrete Fourier Transform ($s = -1$).

'BACKWARD' calculates a backward discrete Fourier Transform ($s = 1$).

The default value of *sign* is FORWARD. The forward and backward transforms are inverses to each other in the following sense: performing the backward transform on a time series of length n followed by the forward transform on the resulting series leads to n times the original series and vice-versa.

OUTFFTC Object

DECLARE OBJECT obj(OUTFFTC) defines an object that is used to collect output from FFTC instance.

OUTFFTC.Collect Method

Usage: *rc* = *obj*.**Collect** *('FFTCObj')* **;**

The method collects the output of discrete Fourier transform from an FFTC instance and saves the result to a CAS table, whose schema is shown in Table 3.3.

Table 3.3 CAS Table Collected with OUTFFTC

Column	Type	Description
X	Numeric	The real part of the discrete Fourier transform of input time series
Y	Numeric	The imaginary part of the discrete Fourier transform of input time series

OUTFFTC.Nrows Attribute

Usage: *nrows* = *obj*.**nrows** *()* ;

This attribute gets the current row count from the OUTFFTC instance.

Example

The following example runs the FFTC class once on the columns that are named x_re and x_im of the mycas.x table and then runs the class again on two input arrays that are named y_re and y_im:

```
data mycas.x;
   input x_re x_im;
   i = _N_;
   datalines;
   1 -1
   2 -2
   3 -3
   4 -4
   ;


proc tsmodel data=mycas.x outobj=(of1=mycas.z1(replace=YES) of2=mycas.z2(replace=YES));
   var x_re x_im;
   id i interval=second;
   require tfa;
   submit;
   declare object f(FFTC);
   declare object of1(OUTFFTC);
   declare object of2(OUTFFTC);
   /* Call FFTC on x_re, x_im column of SAS table mycas.x */
   rc = f.Run("y_re", x_re, "y_im", x_im, "sign", 'forward'); if rc then stop;
   rc = of1.Collect(f); if rc then stop;
   /* Call FFTC on user defined input arrays y_re, y_im */
   array y_re[4]/nosymbols;
   y_re[1]=1; y_re[2]=2; y_re[3]=3; y_re[4]=4;
   array y_im[4]/nosymbols;
   y_im[1]=-1; y_im[2]=-2; y_im[3]=-3; y_im[4]=-4;
   rc = f.Run("y_re", y_re, "y_im", y_im, "sign", 'forward'); if rc then stop;
   rc = of2.Collect(f); if rc then stop;
   endsubmit;
run;
```

HILBERT Class

DECLARE OBJECT *h* (**HILBERT**) ;

DECLARE OBJECT *oh* (**OUTHILBERT**) ;

rc = *h*.**Run** *('Name',Value['Name',Value,...])* ;

rc = *oh*.**Collect** *(h)* ;

The HILBERT class computes the analytic signal that corresponds to a real time series. This analytic signal is a complex time series whose real component is the input time series and whose imaginary component is the discrete Hilbert transform of the input time series.

HILBERT Object

DECLARE OBJECT obj(HILBERT) defines an object that is used to computes an analytic signal that corresponds to a real time series.

HILBERT.Run Method

Usage: *rc* = *obj*.**Run** *('Name',Value['Name',Value,...])* ;

Required Arguments

You must specify the following argument as a '*Name*', *Value* pair:

y specifies an array that represents an input time series. Any missing value is replaced with 0.

OUTHILBERT Object

DECLARE OBJECT obj(OUTHILBERT) defines an object that is used to collect output from a HILBERT instance.

OUTHILBERT.Collect Method

Usage: *rc* = *obj*.*Collect ('HILBERTObj')* ;

This method collects the output of a discrete Hilbert transform from a HILBERT instance and saves the result to a CAS table, whose schema is shown in Table 3.4.

Table 3.4 CAS Table Collected with OUTHILBERT

Column	Type	Description
X	Numeric	The real part of the discrete Fourier transform of input time series
Y	Numeric	The imaginary part of the discrete Fourier transform of input time series

OUTHILBERT.Nrows Attribute

Usage: *nrows* **=** *obj*.**nrows** *()* **;**

This attribute gets the current row count from the OUTHILBERT instance.

Example

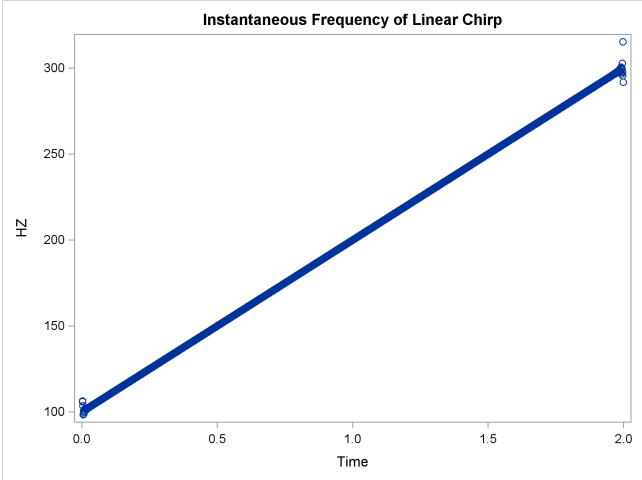
This example uses a time series that is obtained by sampling from a sinusoidal of the form $x(t) = A\cos(2\pi\theta(t) + \phi)$, where $\dot{\theta}(t) = \frac{d\theta(t)}{dt}$ is a linear function of time and is known as a linear chirp. For such a sinusoidal, it is reasonable to interpret $\dot{\theta}(t)$ as the "instantaneous frequency" of $x(t)$, and the Hilbert transform can be used to extract the instantaneous frequency of the linear chirp (Boashash 1992a, b). The following example runs the HILBERT class to compute the instantaneous frequency of a linear chirp:

```
/* Generate a chirp with linear instantaneous frequency.
   The chirp is sampled at 1 kHz for 2 seconds. The instantaneous
   frequency is 100 at t = 0 and 200 Hz at t = 1. */
data mycas.chirp;
   retain pi %sysfunc(constant(pi));
   keep x;
   f0 = 100;
   f1 = 200;
   Fs = 1000;
   do time = 0 to (2-1/Fs) by 1/Fs;
      x = cos(2*pi*(f0*time + 0.5*(f1-f0)*time*time));
      output;
   end;

data mycas.chirp;
    set mycas.chirp;
    i = _N_;


/* Compute the Hilbert transform of the chirp data and use it
compute the instantaneous frequency */
proc tsmodel data=mycas.chirp outobj=(oh=mycas.analytic (replace=YES))
outlog=mycas.log logControl=(warning=keep error=keep note=keep);
   var x;
   id i interval=second;
   require tfa;
   submit;
      declare object h(HILBERT);
      declare object oh(OUTHILBERT);
      rc = h.run('Y', x); if rc then stop;
      rc = oh.Collect(h);
   endsubmit;
run;
```

```
data mycas.analytic;
   set mycas.analytic;
   keep time instfreq;
   time = (_N_ - 1)*(1/1000);
   angle = atan2(Y, X);
   lag_angle = lag(angle);
   diff = angle - lag_angle;
   if diff < -constant('pi') then diff2 = diff + 2*constant('pi');
   else if diff > constant('pi') then diff2 = diff -2*constant('pi');
   else diff2 = diff;
   instfreq = 1000/(2*constant('pi'))*diff2;
   if _N_ >= 3;
run;

proc sgplot data=mycas.analytic;
   title "Instantaneous Frequency of Linear Chirp";
   scatter x=time y=instfreq;
   xaxis label="Time";
   yaxis label="HZ";
run;
```

Output 3.3 shows the results.

Figure 3.3 Instantaneous Frequency of Linear Chirp



PWV Class

DECLARE OBJECT *p* (**PWV**) **;**

DECLARE OBJECT *op* (**OUTPWV**) **;**

rc **=** *p*.**Run** (*'Name',Value['Name',Value,...])* **;**

rc **=** *op*.**Collect** *(p)* **;**

The PWV class computes the pseudo-Wigner-Ville distribution of a real time series.

PWV Object

DECLARE OBJECT obj(PWV) defines an object that is used to compute an analytic signal that corresponds to a real time series.

PWV.Run Method

Usage: *rc* **=** *obj*.**Run** *('Name',Value['Name',Value,...])* **;**

Required Arguments

You must specify the following arguments as '*Name*', *Value* pairs and separated by a comma:

y specifies an array of input time series. The length of this series is denoted in the rest of this section as series_length. Any missing value in this array is replaced with 0 before computation.

window specifies an array of numbers that contains the window values to be used for computation of the pseudo-Wigner-Ville distribution. The length of the window must be odd. The length of the window is denoted as window_length in the rest of this section.

Optional Arguments

You can also specify the following arguments as '*Name*', *Value* pairs, separated by commas:

overlap specifies the extent of overlap between two consecutive windows. The value of *overlap* must be a nonnegative integer that is strictly less than window_length. The default value is $\lfloor \frac{n}{2} \rfloor$, where n = window_length.

fftlen specifies the length of the vector on which the discrete Fourier transform is to be performed. The value of *fftlen* must be a positive integer and must be at least as large as window_length. It is recommended that *fftlen* be a power of two in order to speed up the computation. The default value is the larger of 256 and window_length.

center specifies whether the input time series is centered. You can specify the following values for *center*:

0 does not center the input time series.

1 subtracts the mean of the entire series from each term of the input series before calculating the PWV distribution. The missing values of the input time series are excluded in the calculation of the mean.

The default value of *center* is 0.

nthreads specifies the number of threads to use. The value of *nthreads* must be a nonnegative integer and must not be larger than 128. This argument along with the value of k (see section "OUTPWV.Collect Method" on page 90) determines the number of threads that are used as follows:

- If the value of *nthreads* is strictly positive, then the PWV object attempts to perform the computation using *nthreads* threads.
- If the value of *nthreads* is larger than k, the computation uses only one thread.
- If the value of *nthreads* is 0, then the number of threads that are used is equal to the number of available CPUs.

The default value of *nthreads* is 1.

hilbert_tsf specifies whether to replace the input signal by an analytical signal. You can specify the following values for *hilbert_tsf*:

0 does not replace the input series.

1 replaces the input series by its analytic signal before further computations if the value of *center* is 0; otherwise (the value of *center* is 1), replaces the original signal by the analytic signal that corresponds to the centered signal.

The default value of *hilbert_tsf* is 1.

fade determines the size and alignment of the output. For a description of the impact of this parameter on computation and output size, see the section "Pseudo-Wigner-Ville Distribution" on page 101. The default value of *fade* is 1.

OUTPWV Object

DECLARE OBJECT obj(OUTPWV) defines an object that is used to collect output from a PWV instance.

OUTPWV.Collect Method

Usage: *rc* **=** *obj***.***Collect ('PWVObj')* **;**

This method collects the output of the pseudo-Wigner-Ville transform from a PWV instance and saves the result to a CAS table, whose schema is shown in Table 3.5.

Table 3.5 CAS Table Collected with OUTPWV

Column	Type	Description
Frequency	Numeric	The normalized frequency index
Time	Numeric	The time index
PWV	Numeric	The value of the pseudo-Wigner-Ville distribution

Note: The number of rows in the output table is *fftlen* $\times$ k, where

$$k = \begin{cases} \left\lfloor \dfrac{\text{series\_length} - 1}{\text{window\_length} - \textit{overlap}} \right\rfloor, & \text{when } \textit{fade} = 1 \\ \left\lfloor \dfrac{\text{series\_length} - \textit{overlap}}{\text{window\_length} - \textit{overlap}} \right\rfloor + 1, & \text{when } \textit{fade} = 0 \end{cases}$$

The frequency index starts from 0 and increments in multiples of $\dfrac{1}{2 \times \textit{fftlen}}$. The time index starts from 0 and increments in multiples of window_length – *overlap*.

OUTPWV.Nrows Attribute

Usage: *nrows* **=** *obj***.***nrows ()* **;**

This attribute gets the current row count from the OUTPWV instance.

Example

The following example calls the PWV class on column y of the mycas.a data set:

```
data mycas.a;
   input  y;
   i = _N_;
   datalines;
   3
   1
   4
   2
;


proc tsmodel data=mycas.a outobj=(opwv=mycas.outpwv(replace=YES))
outlog=mycas.log logControl=(warning=keep error=keep note=keep);
   id i interval=seconds;
   var y;
   require tfa;
   submit;
      declare object w(WINDOW);
      declare object pwv(PWV);
      declare object opwv(OUTPWV);
      rc = w.Run('name', 'hamming', 'length', 3);if rc then stop;
      array window[1]/nosymbols;
      rc = w.Save(window); if rc then stop;
      rc = pwv.Run('y', y, 'window', window, 'overlap', 2, 'fftlen', 4, 'fade', 1);
      if rc then stop;
      rc = opwv.Collect(pwv); if rc then stop;
   endsubmit;
run;
```

STFT Class

DECLARE OBJECT *s* (**STFT**) ;

DECLARE OBJECT *os* (**OUTSTFT**) ;

rc = *s*.**Run** ('*Name*',*Value*['*Name*',*Value*,. . .]) ;

rc = *os*.**Collect** (*s*) ;

The STFT class computes the short-time Fourier transform of a real time series. The short-time Fourier transform is a time-frequency distribution; for more information, see the section "Short-Time Fourier Transform" on page 103.

STFT Object

DECLARE OBJECT obj(STFT) defines an object that is used to compute the short-time Fourier transform of a real time series.

STFT.Run Method

Usage: *rc* = *obj*.**Run** ('*Name*',*Value*['*Name*',*Value*,. . .]) ;

Required Arguments

You must specify the following argument as a '*Name*', *Value* pair:

y specifies an array of input time series. Any missing value in this array is replaced with 0 before computation.

Optional Arguments

You can also specify the following arguments as '*Name*', *Value* pairs, separated by commas:

window specifies an array of numbers that contains the window values to be used for the short-time Fourier transform. The default is a Hanning window whose length is the lesser of 256 and the series length.

overlap specifies the extent of overlap between two consecutive windows, where *overlap* must be a nonnegative number that is strictly less than the window length. The default value is $\lfloor \frac{n}{2} \rfloor$, where n is the length of the window.

fftlen specifies the length of the vector on which the discrete Fourier transformation is to be done, where *fftlen* must be a positive integer and must be at least as large as the window length. The default value is the larger of 256 and the window length. It is recommended that *fftlen* be a power of two in order to speed up the computation.

center specifies whether the input time series is centered. You can specify the following values for *center*:

0 does not perform centering.

1 performs centering by subtracting the mean of the entire series from each term of the input series before performing the short-time Fourier transform. Missing values are ignored during the computation of the mean.

The default value of *center* is 0.

nthreads specifies the number of threads to use, where *nthreads* must be a nonnegative integer and must not be larger than 128. The number of threads that are used is determined by the values of *nthreads* and *k* (see the section "Optional Arguments" on page 93).

- If the value of *nthreads* is strictly positive, then the STFT object attempts to perform the computation by using *nthreads* threads.
- If the value of *nthreads* is larger than *k*, the computation uses only one thread.
- If the value of *nthreads* is 0, then the number of threads that are used is equal to the number of available CPUs.

The default value of *nthreads* is 1.

OUTSTFT Object

DECLARE OBJECT obj(OUTSTFT) defines an object that is used to collect output from an STFT instance.

OUTSTFT.Collect Method

Usage: *rc* **=** *obj*.**Collect** *('STFTObj')* **;**

The method collects the output of the short-time Fourier transform from an STFT instance and saves the result to a CAS table, whose schema is shown in Table 3.6.

Table 3.6 CAS Table Collected with OUTSTFT

Column	Type	Description
Frequency	Numeric	The normalized frequency index
Time	Numeric	The time index
Power	Numeric	The power of the time series that corresponds to the current frequency and time index
Amplitude	Numeric	The amplitude of the time series that corresponds to the current frequency and time index
Phase	Numeric	The phase of the time series that corresponds to the current frequency and time index
Coef_re	Numeric	The real part of the Fourier coefficient
Coef_im	Numeric	The imaginary part of the Fourier coefficient

Note: The number of rows in the output table is *fftlen* $\times k$, where $k = \left\lfloor \frac{\text{series\_length} - \textit{overlap}}{\text{window\_length} - \textit{overlap}} \right\rfloor + 1$. The frequency index starts from 0 and increases in increments of $\frac{1}{\textit{fftlen}}$. The time index starts from 0 and increments in multiples of window_length – *overlap*. The power is computed by $x^2 + y^2$, where x is the real part of the Fourier coefficient (the value stored in the sixth column) and y is the imaginary part of the Fourier-coefficient (the value stored in the seventh column). The amplitude is given by $\sqrt{power}$, where *power* is the value stored in the third column. The phase is computed as $\mathrm{atan2}(y, x)$ where x is the real part of the time series (stored in the sixth column) and y is the imaginary part of the time-series (stored in the seventh column).

OUTSTFT.Nrows Attribute

Usage: *nrows* = *obj*.**nrows** *()* **;**

This attribute gets the current row count from the OUTSTFT instance.

Example

The following example calls the STFT class on column y of the mycas.a data table:

```
data mycas.a;
   input  y;
   i = _N_;
   datalines;
   3
   1
   4
   2
;


proc tsmodel data=mycas.a outobj=(os=mycas.outstft(replace=YES))
outlog=mycas.log logControl=(warning=keep error=keep note=keep);
   id i interval=seconds;
   var y;
   require TFA;
   submit;
      declare object w(WINDOW);
      declare object s(STFT);
      declare object os(OUTSTFT);
      /*--- create a hamming window of size 3 ---*/
      rc = w.Run('name', 'hamming', 'length', 3);if rc then stop;
      array window[1]/nosymbols;
      rc = w.Save(window); if rc then stop;
      rc = s.Run('y', y, 'window', window, 'overlap', 2, 'fftlen', 4); if rc then stop;
      rc = os.Collect(s); if rc then stop;
   endsubmit;
run;
```

WINDOW Class

DECLARE OBJECT *w* (**WINDOW**) **;**

DECLARE OBJECT *ow* (**OUTWINDOW**) **;**

rc **=** *w***.Run** (*'Name',Value['Name',Value,...])* **;**

rc **=** *ow***.Collect** (*w*) **;**

The WINDOW class creates a window of a requested type and length. The WINDOW class is useful for smoothing spectra. For more information about the window functions that are implemented in the time-frequency analysis package, see Harris (1978).

WINDOW Object

DECLARE OBJECT obj(WINDOW) defines an object that is used to compute windows.

WINDOW.Run Method

Usage: *rc* **=** *obj***.Run** (*'Name',Value['Name',Value,...])* **;**

Required Arguments

You must specify the following argument as a '*Name*', *Value* pair:

length specifies the length of the requested window.

Optional Arguments

You can also specify the following arguments as '*Name*', *Value* pairs, separated by a comma:

name specifies the type of window. The default is a HANNING window.

In the description of the following window functions, N denotes the length of the window, and the N values that define a window are given by $w[0], \ldots, w[N-1]$. Some windows need additional parameters.

You can specify the following values of *name* within single or double quotation marks:

BARTLETT specifies a Bartlett window. For this window type, you do not need to specify any *params*. This window function is defined as

$$w[i] = 1 - \left| \frac{2i}{N-1} - 1 \right|, \; 0 \le i \le N-1$$

BARTLETT_HANN specifies a Bartlett-Hann window. For this window type, you do not need to specify any *params*. This window function is defined as

$$w[i] = 0.62 - 0.48\left|\frac{i}{N-1} - 0.5\right| - 0.38 \cos \frac{2\pi i}{N-1}, \; 0 \le i \le N-1$$

BLACKMAN specifies a Blackman window. For this window type, you do not need to specify any *params*. This window is defined as

$$w[i] = 0.42 - 0.5\cos\frac{2\pi i}{N-1} + 0.08\cos\frac{4\pi i}{N-1},\ 0 \le i \le N-1$$

BLACKMAN_HARRIS specifies a Blackman-Harris window. For this window type, you do not need to specify any *params*. This window function is defined as

$$\begin{aligned} w[i] =& 0.35875 - 0.48829\cos\frac{2\pi i}{N-1} + 0.14128\cos\frac{4\pi i}{N-1} \\ & - 0.01168\cos\frac{6\pi i}{N-1},\ 0 \le i \le N-1 \end{aligned}$$

BOHMAN specifies a Bohman window. For this window type, you do not need to specify any *params*. This window function is defined as

$$\begin{aligned} w[0] =& w[N-1] = 0 \\ w[i] =& \left(1 - \left|1 - \frac{2i}{N-1}\right|\right)\cos\left(\pi\left|1 - \frac{2i}{N-1}\right|\right) \\ & + \frac{1}{\pi}\sin\left(\pi\left|1 - \frac{2i}{N-1}\right|\right),\ \text{for } 1 \le i \le N-2 \end{aligned}$$

CHEBYSHEV specifies a Chebyshev window. This window function needs one *param*: *att*, whose default value is 100. To define this window, you need to define the nth-degree Chebyshev polynomial, T_n, which is the unique polynomial such that $T_n(\cos\theta) = \cos n\theta$ for all values of θ. $T_n(x)$ can be computed as

$$T_n(x) = \begin{cases} \cos(n\ \cos^{-1} x), & |x| \le 1 \\ \cosh(n\ \operatorname{acosh}(x)), & x > 1 \\ (-1)^n T_n(-x), & x < -1 \end{cases}$$

For odd N (say, $N = 2M + 1$) with $M > 0$, the Chebyshev window of length N can be defined as

$$w[i] = c\left(1 + \frac{2}{T_{2M}(\beta)}\sum_{k=1}^{M} T_{2M}(\beta\cos\frac{k\pi}{N})\cos\frac{2\pi k(i-M)}{N}\right),\ 0 \le i \le N-1$$

where $\beta = \cosh(\operatorname{acosh}(10^{att/20})/(N-1))$ and c is chosen to make the largest term of w equal to 1.

For even N, the Chebyshev window of length N can be defined as

$$w[i] = c \times \left\{\sum_{k=0}^{N-1}(-1)^k T_{N-1}(\beta\cos\frac{k\pi}{N})\cos\frac{\pi k(2i+1)}{N}\right\},\ 0 \le i \le N-1$$

where c is chosen to make the largest term of w equal to 1.

FLAT_TOP specifies a flat-top window. For this window type, you do not need to specify any *params*. This window is function defined as

$$w[i] = 0.21557895 - 0.41663158\cos\frac{2\pi i}{N-1} + 0.277263158\cos\frac{4\pi i}{N-1} - 0.083578947\cos\frac{6\pi i}{N-1} + 0.006947368\cos\frac{8\pi i}{N-1},\ 0 \le i \le N-1$$

GAUSSIAN specifies a Gaussian window. This window function needs one *param*: c, whose default value is 2.5. This window function is defined as

$$w[i] = \exp\left(-\frac{c^2}{2}\left(\frac{i - \frac{N-1}{2}}{\frac{N-1}{2}}\right)^2\right),\ 0 \le i \le N-1$$

HAMMING specifies a Hamming window. For this window type, you do not need to specify any *params*. This window function is defined as

$$w[i] = 0.54 - 0.46\cos\frac{2\pi i}{N-1},\ 0 \le i \le N-1$$

HANNING specifies a Hanning window. For this window type, you do not need to specify any *params*. This window function is defined as

$$w[i] = \frac{1}{2}\left(1 - \cos\frac{2\pi i}{N-1}\right),\ 0 \le i \le N-1$$

KAISER specifies a Kaiser window. This window function needs one *param*: β, whose default value is 0.5. This window function is defined as

$$w[i] = \frac{I_0\left(\beta\sqrt{1-(1-\frac{2i}{N-1})^2}\right)}{I_0(\beta)},\ 0 \le i \le N-1$$

where $I_0(\cdot)$ is the modified Bessel function of the first kind of order 0, which is defined as

$$I_0(x) = \sum_{m=0}^{\infty}\frac{\left(\frac{x}{2}\right)^{2m}}{m!^2}$$

PARZEN specifies a Parzen window. For this window type, you do not need to specify any *params*. This window function is defined as

$$w[i] = \begin{cases} 2\left(1 - \frac{|2i-(N-1)|}{N}\right)^3, & 0 \le i < \frac{N-1}{4} \\ 1 - 6\left(\frac{|2i-(N-1)|}{N}\right)^2 + 6\left(\frac{|2i-(N-1)|}{N}\right)^3, & \frac{N-1}{4} \le i \le \frac{N-1}{2} \\ W[N-i-1], & \frac{N-1}{2} < i \le N-1 \end{cases}$$

The last half of the window is defined by symmetry, which implies $w[i] = w[N-i-1]$ for $0 \le i \le N-1$.

RECTANGULAR specifies a rectangular window. For this window type, you do not need to specify any *params*. This window function is defined as

$$w[i] = 1,\ 0 \le i \le N-1$$

TUKEY specifies a Tukey window. This window function needs one *param*: α, whose default value is 0.5. Let $\epsilon = 10^{-12}$. If $\alpha \ge 1$, then a Hanning window is returned; if $\alpha \le \epsilon$, a rectangular window is returned. For $\epsilon < \alpha < 1$, this window function is defined as

$$w[i] = \begin{cases} \frac{1}{2}(1+\cos\left(\frac{\pi}{\alpha}(\frac{2i}{N-1}-\alpha)\right)), & 0 \le i < \alpha(N-1)/2 \\ 1, & \alpha(N-1)/2 \le i \le (N-1)/2 \\ w[N-i-1], & (N-1)/2 < i <= N-1 \end{cases}$$

The last half of the window is defined by symmetry.

params specifies an array of numbers that specify parameters to be used for creating windows. Not all window types require parameters. When *params* is missing, the default value of *params* is used for any window type that needs a parameter.

WINDOW.Save Method

Usage: *rc* = *obj*.**Save** *(window)* **;**

This method saves the result (window array) to a TKCMP dynamic array. For examples, see the sections "PWV Class" on page 88 and "STFT Class" on page 92.

Required Arguments

You must specify the following argument:

window specifies the TKCMP dynamic array to which to save the result.

OUTWINDOW Object

DECLARE OBJECT obj(OUTWINDOW) defines an object that is used to collect output from a WINDOW instance.

OUTWINDOW.Collect Method

Usage: *rc* = *obj*.**Collect** *('WINDOWObj')* **;**

This method collects an array of numbers that contain the window from a WINDOW instance and saves the result to a CAS table, whose schema is shown in Table 3.7.

Table 3.7 CAS Table Collected with OUTWINDOW

Column	Type	Description
NAME	String	The type of the window
X	Numeric	The array of numbers that contain the window

OUTWINDOW.Nrows Attribute

Usage: *nrows* **=** *obj*.**nrows** *()* **;**

This attribute gets the current row count from the OUTWINDOW instance.

Example

The following DATA step creates a dummy data table:

```
data mycas.dummy;
   dummy = 1;
   i = _N_;
run;
```

The following statements create a Hanning window of length 5 and output it to a CAS table:

```
proc tsmodel data=mycas.dummy outobj=(ow=mycas.outwindow(replace=YES))
outlog=mycas.log logControl=(warning=keep error=keep note=keep);
   var dummy;
   id i interval=seconds;
   require tfa;
   submit;
      declare object w(WINDOW);
      declare object ow(OUTWINDOW);
      rc = w.Run("length", 5, "name", "hanning");
      rc = ow.Collect(w);
   endsubmit;
run;
```

Details

Discrete Fourier Transforms

The discrete Fourier transform $y = \begin{pmatrix} y_0 & y_1 & \dots & y_{n-1} \end{pmatrix}^T$ of a time-series $x = \begin{pmatrix} x_0 & x_1 & \dots & x_{n-1} \end{pmatrix}^T$ can be obtained from the following matrix multiplication:

$$\begin{pmatrix} y_0 \\ y_1 \\ \dots \\ y_{n-1} \end{pmatrix} = \begin{pmatrix} 1 & 1 & 1 & \dots & 1 \\ 1 & \omega & \omega^2 & \dots & \omega^{n-1} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ 1 & \omega^{n-1} & \omega^{2(n-1)} & \dots & \omega^{(n-1)(n-1)} \end{pmatrix} \begin{pmatrix} x_0 \\ x_1 \\ \dots \\ x_{n-1} \end{pmatrix}$$

That is, $y = Wx$, where $\omega = \exp -\frac{2\pi \mathbf{i}}{n}$ and $W = (\omega^{(i-1)(j-1)})_{i,j=0}^{n-1,n-1}$. The backward discrete transform of x can be obtained from the matrix vector product W^*x, where W^* denotes the conjugate transpose of W. W satisfies the relation $WW^* = W^*W = nI$, where I is the identity matrix, thus explaining the inverse relation between the forward and the backward transforms. Even though naive computation of Wx takes $\mathcal{O}(n^2)$ operations, the time-frequency analysis package implementation belongs to class of algorithms known as fast Fourier transforms, which exploit the structure of W to compute the discrete Fourier transform of x in $\mathcal{O}(n \log n)$ operations. For more information, see Van Loan (1992).

Hilbert Transformation

The HILBERT function computes the analytic signal of the input. The analytic signal that corresponds to a continuous time series $x(t)$ is the complex time series $z(t) = x(t) + \mathbf{i}\hat{x}(t)$, where $\hat{x}(t)$ is the Hilbert transform of $x(t)$. In many applications, replacing the original time series by its analytic transform produces better results (Marple 1999).

For a continuous time series $x(t)$ with Fourier transform $X(f) = \int x(t) \exp(-2\pi \mathbf{i} f t)\, dt$, the Hilbert transform is defined by inverting $X(f)$ over the positive frequencies (Cohen 1995, pg 30):

$$\hat{x}(t) = 2 \int_0^\infty X(f) \exp(2\pi i f t)\, df$$

The spectrum of $\hat{x}(t)$ is identical to the spectrum of $x(t)$ for positive frequencies, and the spectrum of $\hat{x}(t)$ is 0 for negative frequencies.

The Hilbert transform of a discrete time series is similarly constructed as a time series whose discrete Fourier transform coincides with that of the input time series for positive spectra and vanishes otherwise. The time-frequency analysis package implementation is based on the method described in Marple (1999).

Time-Frequency Distributions

Time-frequency distributions are standard tools for studying a time series whose frequency behavior varies with time. The discussion here follows the treatment given in Cohen (1995).

An important concept in time frequency analysis is the "energy" of a signal. Let $x(t)$ be a continuous time series with Fourier transform $X(f)$. Then for well-behaved $x(t)$ and $X(f)$, you can consider $\mathrm{E} = \int_{-\infty}^{\infty} |x(t)|^2\, dt = \int_0^{2\pi} |X(f)|^2\, df$ as the "total energy" in $x(t)$, and consequently you can interpret $\int_{t_0}^{t_1} |x(t)|^2\, dt$ as the total energy of $x(t)$ between the time points t_0 and t_1. Similarly you can interpret $\int_{f_0}^{f_1} |X(f)|^2\, df$ to be the energy of $x(t)$ between the frequencies f_0 and f_1. This also implies that $|x(t)|^2 = \lim_{h\to 0} \frac{1}{h} \int_t^{t+h} |x(u)|^2\, du$ can be considered to be the instantaneous energy per unit time at time t and $|X(f)|^2$ can be considered to be the instantaneous energy per unit frequency at f.

A time-frequency distribution of a time series $x(t)$ is a function $P_x(t, f)$ of the time index t and frequency f such that $P_x(t, f)$ is a measure of the intensity of energy of $x(t)$ at time t and frequency f. That is, given a small Δt and small Δf, you should be reasonably able to interpret $P_x(t, f)\Delta t \Delta f$ as the energy of $x(t)$ that can be attributed to $[x, x + \Delta t] \times [f, f + \Delta f]$.

Because energy is positive, you should expect that $P_x(t, f) \geq 0$ for all t and f; this condition is known as positivity. Similarly you should expect $\int_0^{2\pi} P_x(t, f)\, df$ to yield the instantaneous energy at time t, so you should have $\int_0^{2\pi} P_x(t, f)\, df = |x(t)|^2$. Similarly you should expect $\int_{-\infty}^{\infty} P_x(t, f)\, dt = |X(f)|^2$. These two conditions are known as the marginal conditions. Other desirable properties of time-frequency distributions are discussed in Cohen (1995, chapter 6). However, it is not possible for a distribution to simultaneously satisfy positivity and the marginal conditions, and most time-frequency distributions that are used in practice satisfy these conditions only approximately.

The time-frequency analysis package implements the discrete versions of two widely used time-frequency distributions: the pseudo-Wigner-Ville distribution and the short-time Fourier transform. The continuous version of pseudo Wigner-Ville distribution satisfies the marginal property in the special case when it reduces to the Wigner-Ville distribution, but it does not satisfy the positivity condition. The short-time-Fourier transform satisfies the positivity condition, but it does not satisfy the marginal conditions.

Pseudo-Wigner-Ville Distribution

The pseudo-Wigner-Ville distribution is a generalization of the Wigner-Ville distribution. The Wigner-Ville distribution of a continuous time series $x(t)$ is obtained by computing the Fourier transform of $x(t + \tau/2)\overline{x(t - \tau/2)}$ for fixed t as τ varies. So the Wigner-Ville distribution of a continuous, possibly complex-valued, time series $x(t)$ is given by $W_x(t, f)$:

$$\begin{aligned} W_x(t, f) &= \int_{-\infty}^{\infty} x(t + \tau/2)\overline{x(t - \tau/2)} \exp(-2\pi \mathbf{i} f \tau)\, d\tau \\ &= 2\int_{-\infty}^{\infty} x(t + \tau)\overline{x(t - \tau)} \exp(-4\pi \mathbf{i} f \tau)\, d\tau. \end{aligned}$$

It can be shown that the $W_x(t, f)$ is real even when $x(t)$ takes complex values.

The pseudo-Wigner-Ville distribution is a modification of Wigner-Ville distribution that is obtained by an additional term in the defining integral. The pseudo-Wigner-Ville distribution of a continuous time series $x(t)$ is given by

$$W_x(t, f) = \int w(\tau)x(t + \tau/2)\overline{x(t - \tau/2)} \exp(-2\pi \mathbf{i} f \tau)\, d\tau$$

where $w(\tau)$ is a window function.

The Wigner distribution of discrete time series $x[k]$ is defined as follows (Claasen and Mecklenbräuker 1980b, a; Debnath 2002):

$$W_f(n, f) = 2 \sum_{k=-\infty}^{\infty} x[n + k]\overline{x[n - k]} \exp(-4\pi \mathbf{i} f k)$$

From the preceding formula, it follows that $W_n(n, f/2)$ is the discrete-time Fourier transform of $x[n + k]\overline{x[n - k]}$ and provides the basis for the computation here. This also explains why the normalized frequency in the PWV output varies from *0* to $1/2$.

Given an input time series, $x(t)$, the computation can be considered as the evaluation of a function $U_x(n, f)$, which measures the value of the pseudo-Wigner-Ville distribution at time n and frequency $f/2$ for different values of n and f. Now $U_x(n, f)$ can be defined: given a possibly complex-valued time series $x = (x[0], x[2], \ldots, x[L - 1])$ and a window of odd length $2m + 1$, where *window*=$(w[0], \ldots, w[2m])$, define

$$U_x(n, f) = \sum_{k=-m}^{m} w[m + k]x[n + k]\overline{x[n - k]} \exp(-2\pi \mathbf{i} k f)$$

The preceding summation is performed with the following convention: any term in the summation for which both $n + k$ and $n - k$ do not lie between 0 and series_length – 1 is replaced with 0.

Define the following:

- $S =$ window_length $-$ *overlap*
- Let

$$k = \begin{cases} \left\lfloor \dfrac{\text{series\_length} - 1}{S} \right\rfloor, \text{when } \textit{fade} = 1 \\ \left\lfloor \dfrac{\text{series\_length} - \textit{overlap}}{S} \right\rfloor, \text{when } \textit{fade} = 0 \end{cases}$$

- Let

$$c = \begin{cases} 0, \text{when } \textit{fade} = 0 \\ L, \text{when } \textit{fade} = 1 \end{cases}$$

  where the window_length = 2L + 1.

The output of the PWV function consists of the evaluation of $U_x(n, f)$ for $n = c, c + S, c + 2S, \ldots, c + kS$ and for $f = 0, \dfrac{1}{\textit{fftlen}}, \ldots, \dfrac{\textit{fftlen} - 1}{\textit{fftlen}}$.

When *fade* is 0, the output has more observations, but some of the observations correspond to windows where only a portion of the data is available. When *fade* is 1, the output is restricted to windows in which all the data are used.

The pseudo-Wigner-Ville distribution has some undesirable properties. It displays annoying artifacts for multicomponent time series (Cohen 1995), and replacing the input with the analytic signal that corresponds to the input yields better results (Boashash 1988). For this reason, the TFA package provides the *hilbert_tsf* option, which replaces the original series with its analytic signal before computation, and the *center* option, which removes the mean from the series so that an overall mean effect does not show up in the output. Before any computation, the input series is first transformed depending on the value of the *hilbert_tsf* and *center* parameters: First the value of the *center* parameter is checked; if it is 1, then the input series is replaced by the centered series that is obtained by subtracting the series mean from each term of the series. If the value of the *hilbert_tsf* parameter is also 1, this possibly centered series is replaced by the analytic signal that corresponds to the centered input.

Short-Time Fourier Transform

The short-time Fourier transform (STFT) computations consist of multiple "local" discrete Fourier transform computations. The input time series is divided into multiple contiguous blocks, and their discrete Fourier transforms are computed in succession. The use of window functions makes the spectra smooth.

Given a time series $x[0], x[1], \ldots, x[L-1]$ and a window $w[0], \ldots, w[m]$, the computation of STFT can be considered to be the evaluation of a function $S_x(n, f)$, which measures the strength of the frequency f at time n for different values of n and f, where $S_x(n, f)$ is defined as

$$S_x(n, f) = \sum_{k=0}^{m-1} x[n+k]w[k]\exp(-\mathrm{i}2\pi k f)$$

Let $k = \left\lfloor \frac{\text{series\_length} - \textit{overlap}}{\text{window\_length} - \textit{overlap}} \right\rfloor + 1$ and $S = \text{window\_length} - \textit{overlap}$. Then STFT consists of the computation of $S_x(n, f)$ for $n = 0, S, 2S, \ldots, kS$ and for $f = 0, \frac{1}{\textit{fftlen}}, \ldots, \frac{\textit{fftlen} - 1}{\textit{fftlen}}$.

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Chapter 4

Time Series Analysis Package for the TSMODEL Procedure

Contents

Overview

The time series analysis (TSA) package contains a set of time series analysis functions that can be used as part of the programming statements in the TSMODEL procedure. This package provides a flexible way to analyze time series within the procedure.

NOTE: Each function in this chapter has a prefix of "TSA."; however, the prefixes are omitted in descriptions for better readability. The mycas libref in the examples refers to Sasioca library that is linked to a caslib. The mycas.air data table that is used in the examples refers to Sashelp.Air data. All the examples in this chapter

assume that your CAS engine libref is named mycas, but you can substitute any appropriately defined CAS engine libref. For more information about CAS engine librefs, see *SAS Cloud Analytic Services: Language Reference*.

Functional Summary

Table 4.1 summarizes the functions in the TSA package.

Table 4.1 Functions in Time Series Analysis Package

TSA Function	Description
ACCUMULATE	Accumulates a univariate time series to a particular frequency
ACCUMULATE2	Accumulates a high-frequency time series to a lower frequency and expands the lower-frequency series to have the same length as the high-frequency series
ACF	Computes autocorrelation and autocovariance for a time series array
ARMAORDERS	Performs tests to tentatively identify the autoregressive and moving average orders of mixed autoregressive moving average models
CCF	Computes the cross-correlation and cross-covariance for two time series arrays
DPF Class Object	Performs count distribution analysis for time series
FREQ Class Object	Performs frequency analysis of a time series
INTERMITTENCYTEST	Tests for intermittency of a univariate time series
IACF	Computes the inverse autocorrelation for a time series array
MOVINGSUMMARY	Computes statistics for a set of values within a moving time window
PACF	Computes the partial autocorrelation for a time series array
SCALE	Scales a time series between the minimum value and the maximum value of the original time series
SEASONALDECOMP	Computes the seasonal indices of a univariate time series using classical decomposition
SEASONALINDICES	Computes the seasonal indices of a univariate time series by using regression seasonal dummies
SEASONTEST	Tests for seasonality of a univariate time series
SIMILARITY	Performs similarity analysis for time series
STATIONARITYTEST	Tests for stationarity of a univariate time series
TRANSFORM	Transforms time series according to the specified transformation type

Table 4.1 *continued*

TSA Function	Description
UNBIASEDNESS	Tests whether a univariate time series is unbiased
WHITENOISE	Tests for white noise of a time series array

ACCUMULATE Function

rc = **TSA.ACCUMULATE** *(time, y, 'interval', id, z, <'accumulate'>, <'setmiss'>, <'zeromiss'>)* **;**

The ACCUMULATE function accumulates a univariate time series to a particular frequency.

Required Arguments

You must specify the following arguments, separated by commas:

time specifies the time ID array for the time series.

y specifies the times series array to accumulate.

'*interval*' specifies the time interval.

You can specify the following values within single quotation marks:

DAY specifies a seasonal cycle of length 7.

MONTH specifies a seasonal cycle of length 12.

QTR specifies a seasonal cycle of length 4.

Optional Arguments

You can also specify the following arguments, separated by commas. If you want to use a default value for any of these arguments, enter a space for it.

'*accumulate*' specifies the accumulation statistic.

You can specify the following values within single quotation marks:

AVERAGE | AVG specifies the average of the values in the time series.

CSS specifies the corrected sum of squares of the values in the time series.

FIRST specifies the first value of the time series.

LAST specifies the last value of the time series.

MAXIMUM | MAX specifies the maximum value in the time series.

MEDIAN | MED specifies the median of the values in the time series.

MINIMUM | MIN specifies the minimum value in the time series.

N specifies the number of nonmissing observations.

NMISS specifies the number of missing observations.

NOBS specifies the number of observations.

STDDEV | STD specifies the standard deviation of the values in the time series.

TOTAL specifies the total sum of the values in the time series.

USS specifies the uncorrected sum of squares of the values in the time series.

The default is TOTAL.

'*setmiss*' specifies the missing value interpretation.

You can specify the following values within single quotation marks:

AVERAGE | AVG specifies the accumulated average value.

FIRST specifies the accumulated first nonmissing value.

MAXIMUM | MAX specifies the accumulated maximum value.

MEDIAN | MED specifies the accumulated median value.

MINIMUM | MIN specifies the accumulated minimum value.

MISSING specifies a missing value.

NEXT specifies the next period's accumulated nonmissing value. Missing values at the end of the accumulated series remain missing.

PREVIOUS | PREV specifies the previous period's accumulated nonmissing value. Missing values at the beginning of the accumulated series remain missing.

The default is MISSING.

'*zeromiss*' specifies the zero value interpretation.

You can specify the following values within single quotation marks:

BOTH sets both beginning and ending zeros to missing.

LEFT sets beginning zeros to missing.

NONE leaves beginning and ending zeros unchanged.

RIGHT sets ending zeros to missing.

The default is NONE.

Returned Values

The ACCUMULATE function returns the following values:

rc returns one of the following scalar return codes:

rc	**Termination Reason**
0	Success
< 0	Computational failure

id returns the time ID array for the accumulated time series.

z returns the accumulated time series array.

Example

This example uses the TSMODEL procedure to accumulate a time series:

```
proc tsmodel data=mycas.air outarray=mycas.outarray;
   id date interval=month;
   var air;
   outarray qtravg new_id;
   require tsa;
   submit;
   declare object TSA(tsa);
   rc=TSA.ACCUMULATE(date, air, 'QTR', new_id, qtravg, 'AVERAGE', , );
   endsubmit;
run;
```

ACCUMULATE2 Function

rc = **TSA.ACCUMULATE2** *(time, y, 'interval', id, z, <'accumulate'>, <'setmiss'>, <'zeromiss'>)* **;**

The ACCUMULATE2 function accumulates a high-frequency time series to a lower frequency and expands the lower-frequency time series to the same length as the high-frequency series.

Required Arguments

You must specify the following arguments, separated by commas:

time specifies the time ID array for the time series.

y specifies the times series array to accumulate.

'*interval*' specifies the time interval.

You can specify the following values within single quotation marks:

DAY specifies a seasonal cycle of length 7.

MONTH specifies a seasonal cycle of length 12.

QTR specifies a seasonal cycle of length 4.

Optional Arguments

You can also specify the following arguments, separated by commas. If you want to use a default value for any of these arguments, enter a space for it.

'*accumulate*' specifies the accumulation statistic.

You can specify the following values within single quotation marks:

AVERAGE | AVG specifies the average of the values in the time series.

CSS specifies the corrected sum of squares of the values in the time series.

FIRST specifies the first value of the time series.

LAST specifies the last value of the time series.

MAXIMUM | MAX specifies the maximum value in the time series.

MEDIAN | MED specifies the median of the values in the time series.

MINIMUM | MIN specifies the minimum value in the time series.

N specifies the number of nonmissing observations.

NMISS specifies the number of missing observations.

NOBS specifies the number of observations.

STDDEV | STD specifies the standard deviation of the values in the time series.

TOTAL specifies the total sum of the values in the time series.

USS specifies the uncorrected sum of squares of the values in the time series.

The default is TOTAL.

'*setmiss*' specifies the missing value interpretation.

You can specify the following values within single quotation marks:

AVERAGE | AVG specifies the accumulated average value.

FIRST specifies the accumulated first nonmissing value.

LAST specifies the accumulated last nonmissing value.

MAXIMUM | MAX specifies the accumulated maximum value.

MEDIAN | MED specifies the accumulated median value.

MINIMUM | MIN specifies the accumulated minimum value.

MISSING specifies a missing value.

NEXT specifies the next period's accumulated nonmissing value. Missing values at the end of the accumulated series remain missing.

PREVIOUS | PREV specifies the previous period's accumulated nonmissing value. Missing values at the beginning of the accumulated series remain missing.

The default is MISSING.

'*zeromiss*' specifies the zero value interpretation.

You can specify the following values within single quotation marks:

BOTH sets both beginning and ending zeros to missing.

LEFT sets beginning zeros to missing.

NONE leaves beginning and ending zeros unchanged.

RIGHT sets ending zeros to missing.

The default is NONE.

Returned Values

The ACCUMULATE2 function returns the following values:

rc returns one of the following scalar return codes:

rc	**Termination Reason**
0	Success.
< 0	Computational failure.

id returns the time ID array for the accumulated time series.

z returns the accumulated time series array.

Example

This example uses the TSMODEL procedure to accumulate a monthly time series into a yearly time series:

```
proc tsmodel data=mycas.air outarray=mycas.outarray;
   id date interval=month;
   var air;
   outarray yearavg_expand yearid_expand;
   require tsa;
   submit;
   declare object TSA(tsa);
   rc=TSA.ACCUMULATE2(date, air, 'YEAR', yearid_expand, yearavg_expand,
                      'AVERAGE', , );
   endsubmit;
run;
```

ACF Function

rc = **TSA.ACF** *(y, nlag, lags, df, < mu >, < acov >, < acf >, < acfstd >, < acf2std >, < acfnorm >, < acfprob > < acflprob >)* **;**

The ACF function computes autocorrelation and autocovariance for a time series array.

Required Arguments

You must specify the following arguments, separated by a comma:

y specifies the times series array.

nlag specifies the number of the lag to use in the calculation.

Returned Values

The ACF function returns the following values:

rc returns one of the following scalar return codes:

rc	**Termination Reason**
0	Success
< 0	Computational failure

lags returns the number of the lags that were used in the calculation.

df returns the number of observations used to compute *acov* and *acf*.

Optional Returned Values

You can also specify the following arguments, separated by commas to request additional returned values. If you do not want the value to be returned, enter a space for it.

mu returns the mean estimate.

acov returns an array of covariance estimates, with *nlag*+1 entries.

acf returns an array of autocorrelation estimates, with *nlag*+1 entries.

acfstd returns an array of standard errors, with *nlag*+1 entries.

acf2std returns an array of twice standard errors, with *nlag*+1 entries.

acfnorm returns an array of normalized autocorrelation, with *nlag*+1 entries.

acfprob returns an array of autocorrelation probabilities, with *nlag*+1 entries.

acflprob returns an array of autocorrelation log probabilities, with *nlag*+1 entries.

Example

This example uses the TSMODEL procedure to compute the autocorrelation of lag 3 of the time series Air:

```
proc tsmodel data=mycas.air outscalars=mycas.outscalars
              outarray=mycas.outarray;
   id date interval=month;
   var air;
   outscalars mu;
   outarrays acf acov lags df acfstd;
   require tsa;
   submit;
   declare object TSA(tsa);
   rc=TSA.ACF(air, 3, lags, df, mu, acov, acf, acfstd, , , , );
   endsubmit;
run;
```

ARMAORDERS Function

rc = **TSA.ARMAORDERS** *(y, < dif >, < 'method' >, < p >, < q >, < perror >, porders, qorders)* **;**

The ARMAORDERS function performs tests to tentatively identify the autoregressive and moving average orders of mixed autoregressive moving average models.

Required Arguments

You must specify the following argument:

y specifies the times series array to test.

Optional Arguments

You can also specify the following arguments, separated by commas. If you want to use a default value for any of these arguments, enter a space for it.

dif specifies either an array of positive integers or a positive integer that is used for differencing. The default value is 0.

'*method*' specifies the method of tentative order selection.

You can specify the following values within single quotation marks:

ESACF specifies the extended sample autocorrelation function.

MINIC specifies the minimum information criterion.

SCAN specifies the squared canonical correlations.

The default value is MINIC.

p specifies the autoregressive order range, where *p* is an array of two nonnegative integers that define the minimum and maximum values.

By default, *p* is the array [0,5].

q specifies the moving average order range, where *q* is an array of two nonnegative integers that define the minimum and maximum values.

By default, *q* is the array [0,5].

perror specifies the autoregressive orders used to estimate the error series for the MINIC method, where *perror* is an array of two nonnegative integers that define the minimum and maximum values.

By default, *perror* is the array [$\max(p)$, $\max(p)+\max(q)$].

Returned Values

The ARMAORDERS function returns the following values:

rc returns one of the following scalar return codes:

rc	Termination Reason
0	Success
< 0	Computational failure

porders returns the recommended autoregressive orders.

qorders returns the recommended moving average orders.

Example

This example uses the TSMODEL procedure to tentatively identify the autoregressive and moving average orders for the time series Air:

```
proc tsmodel data=mycas.air outscalars=mycas.outscalars;
   id date interval=month;
   var air;
   outscalars porders qorders;
   require tsa;
   submit;
   declare object TSA(tsa);
   porders = 0;
   qorders = 0;
   Array P[2]/nosymbols; P[1]=0; P[2]=5;
   Array Q[2]/nosymbols; Q[1]=0; Q[2]=5;
   rc=TSA.ARMAORDERS(air, 0, 'SCAN', P, Q, , porders, qorders);
   rc=TSA.ARMAORDERS(air, 1, 'ESACF', P, Q, , porders, qorders);
   rc=TSA.ARMAORDERS(air, 1, 'MINIC', P, Q, ,porders, qorders);
   endsubmit;
run;
```

CCF Function

rc **= TSA.CCF** *(y, x, nlag, lags, df, < ymu > , < xmu >, < ccov >, < ccf >, < ccfstd >, < ccf2std >, < ccfnorm >, < ccfprob >, < ccflprob >)* **;**

The CCF function computes the cross-correlation and cross-covariance for two time series arrays.

Required Arguments

You must specify the following arguments, separated by commas:

y specifies one times series array.

x specifies the other time series array.

nlag specifies the number of the lag to compute.

Returned Values

The CCF function returns the following values:

rc returns one of the following scalar return codes:

rc	**Termination Reason**
0	Success
< 0	Computational failure

lags returns an array of lags that were computed, with *nlag*+1 entries.

df returns an array of number of products for which to compute the cross-correlation, with *nlag*+1 entries.

Optional Returned Values

You can also specify the following arguments, separated by commas to request additional returned values. If you do not want the value to be returned, enter a space for it.

ymu returns the mean estimate of input time series *y*.

xmu returns the mean estimate of input time series *x*.

ccov returns an array of cross-covariance estimates, with $2 \times nlag + 1$ entries.

ccf returns an array of cross-correlation estimates, with $2 \times nlag + 1$ entries.

ccfstd returns an array of standard errors, with $2 \times nlag + 1$ entries.

ccf2std returns an array of double standard errors, with $2 \times nlag + 1$ entries.

ccfnorm returns an array of normalized cross-correlation, with $2 \times nlag + 1$ entries.

ccfprob returns an array of probabilities, with $2 \times nlag + 1$ entries.

ccflprob returns an array of log probabilities, with $2 \times nlag + 1$ entries.

Example

This example uses the TSMODEL procedure to compute the cross-correlation and cross-covariance of two time series arrays (Price and Sale) with lag 20:

```
proc tsmodel data=mycas.pricedata outarray=mycas.ccf_array
             outscalar=mycas.ccf_scalar;
   id date interval=month;
   var price sale;
   by region line product;
   outscalars ymu xmu;
   outarrays lags df ccov ccf ccfstd ccf2std ccfnorm ccfprob ccflprob;
   require tsa;
   submit;
   declare object TSA(tsa);
   rc=TSA.CCF(price, sale, 20, lags, df, ymu, xmu, ccov, ccf,
             ccfstd, ccf2std, ccfnorm, ccfprob, ccflprob);
   endsubmit;
run;
```

DPF Class Object

The DPF class object functions take the output of the FREQ class object as input. The DPF class object performs count distribution analysis for a time series.

Signature

```
declare object f(FREQ);
declare object of(OUTFREQ);
declare object dpf(DPF);
declare object odpe(OUTDPE);
declare object odprob(OUTDPROB);
rc = f.Initialize();
rc = f.SetY(claims);
rc = f.SetOption(<'name',value, 'name', value, ...>);
rc = f.Run();
rc = of.Collect(f);

rc = dpf.Initialize(f);
```

```
rc = dpf.SetOption(<'name',value, 'name', value, ...>);
rc = dpf.Run();
rc = odpe.Collect(dpf);
rc = odprob.Collect(dpf);
```

Required Input

You must specify a FREQ object through the Initialize() statement:

'*freq*' specifies a FREQ class object, which includes frequency analysis results.

Optional Specifications

You can optionally specify one or more of the following '*Name*', *Value* pairs, separated by commas, in the SetOption() statement:

'*alpha*' specifies the confidence level size, where *alpha* must be between 0 and 1. The default value is 0.05.

'*converge*' specifies the convergence criterion.

'*maxiter*' specifies the maximum number of iterations, where *maxiter* is an integer.

'*select*' specifies the distribution selection criterion.

You can specify the following values within single quotation marks:

AIC specifies Akaike's information criterion.

BIC specifies the Bayesian information criterion.

LOGLIK specifies the log-likelihood.

The default value is LOGLIK.

'*method*' specifies candidate distribution to use in the analysis.

You can specify the following values within single quotation marks:

BEST specifies the best distribution, based on the value of the *select* argument.

BINOMIAL specifies the binomial distribution.

GEOMETRIC specifies the geometric distribution.

NEGBINOMIAL specifies the negative binomial distribution.

POISSON specifies the Poisson distribution.

ZMBINOMIAL specifies the zero-modified binomial distribution.

ZMGEOMETRIC specifies the zero-modified geometric distribution.

ZMNEGBINOMIAL specifies the zero-modified negative binomial distribution.

ZMPOISSON specifies the zero-modified Poisson distribution.

The default distribution is BEST.

Returned Values

The Run() statement returns the following values:

rc returns one of the following scalar return codes:

rc	**Termination Reason**
0	Successful
< 0	Computational failure

Output Table Schema

Two collector objects, OUTDPE and OUTDPROB, collect the results of the count distribution analysis. Results can be output to tables using OUTOBJ=() statement.

OUTDPE collects parameter estimates information of selected count distribution. The output table contains the following columns:

Column Name	**Column Content**
NAME	Name of target variable
Distribution	Distribution
Parameter	Name of parameter
Estimate	Parameter estimate
StdErr	Standard error
Tvalue	*t* value
Probt	Approximate probability > |*t*|
Lower	Lower 95% of parameter estimate
Upper	Upper 95% of parameter estimate

OUTDPROB collects predictions using the count distribution that has the best fit. The output table contains the following columns:

Column Name	Column Content
NAME	Name of target variable
Index	Index
Value	Values
Observedzeros	Observed zeros
Expectedzeros	Expected zeros
Observed	Observed counts
Expected	Expected counts
Expectedlower	Expected lower confidence
Expectedupper	Expected upper confidence
Probability	Probability
Probabilitylower	Probability lower confidence
Probabilityupper	Probability upper confidence
Chisquare	Chi-square statistic
Chisquareprob	Chi-square probability
Chisquarelogprob	Chi-square log probability

Example

This example uses the TSMODEL procedure to analyze the frequency of the time series Air and then conducts a count distribution analysis:

```
proc tsmodel data=mycas.air outobj=(of=mycas.outfreq(replace=YES)
                                    odpe=mycas.dpe(replace=YES)
                                    odprob=mycas.dprob(replace=YES)
                                    );
   var air;
   id date interval=month;
   require tsa;
   submit;
    declare object f(FREQ);
    declare object of(OUTFREQ);
    declare object dpf(DPF);
    declare object odpe(OUTDPE);
    declare object odprob(OUTDPROB);
    rc = f.Initialize();
    rc = f.SetOption("SEASONALITY",12);
    rc = f.SetY(air);
    rc = f.Run();
    rc = of.Collect(f);

    rc = dpf.Initialize(f);
    rc = dpf.SetOption("SELECT","AIC","METHOD","POISSON");
    rc = dpf.Run();
    rc = odpe.Collect(dpf);
    rc = odprob.Collect(dpf);
   endsubmit;
run;
```

FREQ Class Object

The FREQ class object function analyzes the frequency of a time series and outputs all unique values and corresponding counts for the time series.

Signature

```
declare object f(FREQ);
declare object of(OUTFREQ);
rc = f.Initialize();
rc = f.SetY(claims);
rc = f.SetOption(<'name',value, 'name', value, ...>);
rc = f.Run();
rc = of.Collect(f);
```

Required Input

You must specify the following input series through the SetY() statement:

y specifies the times series array to analyze.

Optional Specification

You can optionally specify the following '*Name*', *Value* pair, in the SetOption() statement:

seasonality specifies the seasonality of the time series, where *seasonality* is an integer. The default value is 0.

Returned Values

The Run() statement returns the following values:

rc returns one of the following scalar return codes:

rc	**Termination Reason**
0	Successful
1	Binary series
2	Nonnegative integer series
3	Integer series
4	Noninteger series
< 0	Computational failure

Output Table Schema

The collector object, OUTFREQ, collects the results of frequency function. Results can be output to a table using the OUTOBJ=() statement.

OUTFREQ collects the results of frequency function. The output table contains the following columns:

Column Name	Column Content
NAME	Name of target variable
Values	Array of series values
Counts	Array of frequency series counts
Percent	Percentage of total frequency

Example

This example uses the TSMODEL procedure to analyze the frequency of the time series Air:

```
proc tsmodel data=mycas.air outobj=(of=mycas.outfreq(replace=YES));
   var air;
   id date interval=month;
   require tsa;
   submit;
    declare object f(FREQ);
    declare object of(OUTFREQ);
    rc = f.Initialize();
    rc = f.SetOption("SEASONALITY",12);
    rc = f.SetY(air);
    rc = f.Run();
    rc = of.Collect(f);
   endsubmit;
run;
```

IACF Function

rc = **TSA.IACF** *(y, nlag, lags, df, <mu>, <iacf>, <iacfstd>, <iacf2std>, <iacfnorm>, <iacfprob>, <iacflprob>)* **;**

The IACF function computes the inverse autocorrelation for a time series array.

Required Arguments

You must specify the following arguments, separated by a comma:

y specifies the times series array.

nlag specifies the number of the lag to use in the calculation.

Returned Values

The IACF function returns the following values:

rc returns one of the following scalar return codes:

rc	**Termination Reason**
0	Success
< 0	Computational failure

lags returns the number of the lag that was used in the calculation.

df returns the number of observations used to compute *iacf*.

Optional Returned Values

You can also specify the following arguments, separated by commas to request additional returned values. If you do not want the value to be returned, enter a space for it.

mu returns the mean estimate.

iacf returns an array of inverse autocorrelation estimates, with *nlag*+1 entries.

iacfstd returns an array of inverse autocorrelation standard errors, with *nlag*+1 entries.

iacf2std returns an array of twice standard errors, with *nlag*+1 entries.

iacfnorm returns an array of normalized inverse autocorrelation, with *nlag*+1 entries.

iacfprob returns an array of inverse autocorrelation probabilities, with *nlag*+1 entries.

iacflprob returns an array of inverse autocorrelation log probabilities, with *nlag*+1 entries.

Example

This example uses the TSMODEL procedure to compute the inverse autocorrelation of lag 3 of the time series Air:

```
proc tsmodel data=mycas.air outscalars=mycas.outscalars
             outarray=mycas.outarray;
   id date interval=month;
   var air;
   outscalars mu;
   outarrays iacf lags df iacfstd;
   require tsa;
```

```
   submit;
   declare object TSA(tsa);
   rc=TSA.IACF(air, 3, lags, df, mu, iacf, iacfstd, , , , );
   endsubmit;
run;
```

INTERMITTENCYTEST Function

rc = **TSA.INTERMITTENCYTEST** *(y, base, threshold, med)* **;**

The INTERMITTENCYTEST function tests for intermittency of a univariate time series by computing the median of the length of contiguous constant periods (demand intervals).

Required Arguments

You must specify the following arguments, separated by commas:

y specifies the times series array to test. The test is applied to the last 100 values.

base specifies the base value to test. The value is typically 0.

threshold specifies the threshold value for intermittency. The value is typically greater than 2.

Returned Values

The INTERMITTENCYTEST function returns the following values:

rc returns one of the following scalar return codes:

rc	**Termination Reason**
0	Time series is not intermittent
1	Time series is intermittent
< 0	Computational failure

med returns the median length of the contiguous constant periods.

Example

This example uses the TSMODEL procedure to test the intermittency on the time series array Air:

```
proc tsmodel data=mycas.air outscalars=mycas.outscalars;
   id date interval=month;
   var air;
   outscalars intermittent;
```

```
    require tsa;
    submit;
    declare object TSA(tsa);
    intermittent=0;
    rc=TSA.INTERMITTENCYTEST(air, 0, 2, med);
    if rc>0 then intermittent= 1;
    endsubmit;
  run;
```

MOVINGSUMMARY Function

rc = **TSA.MOVINGSUMMARY** *(y, 'method', k, <lead>, <w>, <'setmiss'>, <'abs'>, x, <p>, <nmiss>)* **;**

The MOVINGSUMMARY function computes statistics for a set of values within a moving time window.

Required Arguments

You must specify the following arguments, separated by commas:

y specifies the input time series array.

'*method*' specifies the statistic to calculate for each output array, x_t, based on the elements of the y input array in the t window.

You can specify the following methods within single quotation marks:

EWMA	calculates the exponentially weighted moving average.
GMEAN	calculates the moving geometric mean.
MAX	calculates the maximum value.
MEAN	calculates the moving average.
MED	calculates the median value.
MIN	calculates the minimum value.
PROD	calculates the moving product.
RANGE	calculates the maximum value minus minimum value.
SUM	calculates the moving sum.
TVALUE	calculates the mean divided by the standard deviation.
VAR	calculates the variance of the sample defined by the window around t.

k specifies the window size, where k is a positive integer. When the method is EWMA, k is set to 1 and defaults are used for all other arguments.

Optional Arguments

You can also specify the following arguments, separated by commas. If you want to use a default value for any of these arguments, enter a space for it.

lead specifies the number of leading terms, where *lead* is a nonnegative integer less than *k*. You can specify the following values:

- **0** specifies the backward moving summary.
- *k*/2 specifies the centered moving summary.
- *k*–1 specifies the forward moving summary.

The default value is 0. When the method is EWMA, *lead* is set to 0.

w specifies an array of weights that has *k* elements (a scalar when *k*=1). This argument is required for the EWMA method, and it must be a scalar between 0 and 1, inclusive. This argument is optional for the MEAN, PROD, TVALUE, and VAR methods and is not supported for all other methods.

'*setmiss*' specifies how missing values are interpreted.

You can specify the following values within single quotation marks:

- **IGNORE** specifies that missing values have no effect on the summary.
- **MEAN** specifies that missing values are replaced with the mean of the remaining nonmissing values in the window. This value is supported only for the method SUM.
- **MISSING** specifies that if the input window contains a missing value, the output value is also missing.

The default value is IGNORE.

'*abs*' specifies how the series is transformed into nonnegative values prior to performing the moving summary.

You can specify the following values within single quotation marks:

- **OFF** specifies no modification. This value is not supported for the GMEAN method, because the geometric mean is undefined for negative values in the series.
- **ON** transforms each member of the series into its absolute value.
- **SQUARE** transforms each member of the series into its square

The default value is ON when the *method* is GMEAN and is OFF for all other *methods*.

Returned Values

The MOVINGSUMMARY function returns the following values:

rc returns one of the following scalar return codes:

rc	**Termination Reason**
4	Warping limits relaxed
3	Expansion limits relaxed
2	Compression limits relaxed
1	Warping limits imposed
0	Success
< 0	Computational failure

x returns the transformed series.

Optional Returned Values

You can also specify the following arguments, separated by commas to request additional returned values. If you do not want the value to be returned, enter a space for it.

p returns an array in which element *t* is the number of products that contributed to element *t* of *x*. The *p* argument is supported only when *method* is PROD or GMEAN.

nmiss returns the number of missing values that are generated.

Examples

This example uses the TSMODEL procedure to compute the five-period moving average of the time series array Air:

```
proc tsmodel data=mycas.air outscalar=mycas.scalars outarray=mycas.arrays;
   id date interval=month;
   var air;
   outarrays x p;
   outscalars rc nmiss;
   require tsa;
   submit;
   declare object TSA(tsa);
   rc=TSA.MOVINGSUMMARY(air, 'MEAN' , 5, 0 , , , , x, p, nmiss);
   endsubmit;
run;
```

This example uses the TSMODEL procedure to compute the five-period centered weighted moving product of the time series array Air:

```
proc tsmodel data=mycas.air outscalar = mycas.scalars outarray=mycas.arrays;
   id date interval=month;
   var air;
   Array w[5]/nosymbols; w[1]=0.3; w[2]=0.2; w[3]=0.25; w[4]=0.1; w[5]=0.15;
   outarrays x;
   outscalars rc;
```

```
    require tsa;
    submit;
    declare object TSA(tsa);
    rc=TSA.MOVINGSUMMARY(air, 'PROD' , 5, 2.5 , w, , , x, , );
    endsubmit;
  run;
```

PACF Function

rc = **TSA.PACF** *(y, nlag, lags, df, < mu >, < pacf >, < pacfstd >, < pacf2std >, < pacfnorm >, < pacfprob >, < pacflprob >)* **;**

The PACF function computes the partial autocorrelation for a time series array.

Required Arguments

You must specify the following arguments, separated by a comma:

y specifies the times series array.

nlag specifies the number of the lag to use in the calculation.

Returned Values

The PACF function returns the following values:

rc returns one of the following scalar return codes:

rc	**Termination Reason**
0	Success
< 0	Computational failure

lags returns the number of the lag that was used in the calculation.

df returns the number of observations used to compute *pacf*.

Optional Returned Values

You can also specify the following arguments, separated by commas to request additional returned values. If you do not want the value to be returned, enter a space for it.

mu returns the mean estimate.

pacf returns an array of partial autocorrelation estimates, with *nlag*+1 entries.

pacfstd returns an array of partial autocorrelation standard errors, with *nlag*+1 entries.

pacf2std returns an array of twice standard errors, with *nlag*+1 entries.

pacfnorm returns an array of normalized partial autocorrelation, with *nlag*+1 entries.

pacfprob returns an array of partial autocorrelation probabilities, with *nlag*+1 entries.

pacflprob returns an array of partial autocorrelation log probabilities, with *nlag*+1 entries.

Example

This example uses the TSMODEL procedure to compute the autocorrelation of lag 3 of the time series Air:

```
proc tsmodel data=mycas.air outscalars=mycas.outscalars
              outarray=mycas.outarray;
   id date interval=month;
   var air;
   outscalars mu;
   outarrays pacf lags df pacfstd;
   require tsa;
   submit;
   declare object TSA(tsa);
   rc=TSA.PACF(air, 3, lags, df, mu, pacf, pacfstd, , , , );
   endsubmit;
run;
```

SCALE Function

rc = **TSA.SCALE** *(y, min, max, nomiss, x, < nmiss >)* **;**

The SCALE function scales a time series between a specified minimum value and a specified maximum value.

Required Arguments

You must specify the following arguments, separated by commas:

y specifies the input time series array.

min specifies the minimum value in the output array.

max specifies the maximum value in the output array.

nomiss specifies how missing values are treated. You can specify the following values:

0 allows missing values in the input array.

1 does not allow missing values in the input array. If missing values exist, the output array x_t becomes missing for all values of t.

The default is 0.

Returned Values

The SCALE function returns the following values:

rc returns one of the following scalar return codes:

rc	**Termination Reason**
5	The input series is nearly constant
4	Missing values were found when the value 1 was specified for *nomiss*
3	One or more arguments are ignored
2	One or more arguments are set to the default value
1	The input series is all missing
–1	One or more arguments are not supported
–2	The minimum value of the transformed series is greater than its maximum value
–4	Extreme slope
–99	Bad arguments

x returns the transformed series.

Optional Returned Values

You can also specify the following argument to request an additional returned value:

nmiss returns the number of missing values that are generated.

Example

This example uses the TSMODEL procedure to scale the time series array Air between a minimum value of 0 and a maximum value of 100:

```
proc tsmodel data=mycas.air outarray=mycas.trans_array;
   var air;
   require tsa;
   submit;
   declare object TSA(tsa);
   outarrays t1;
   rc=TSA.SCALE(air, 0, 100, , t1, );
   endsubmit;
run;
```

SEASONALDECOMP Function

rc = **TSA.SEASONALDECOMP** *(y, s, 'mode', <lambda>, <tcc>, <sic>, <sc>, <scstd>, <tcs>, <ic>, <sa>, <pcsa>, <tc>, <cc>)* **;**

The SEASONALDECOMP function computes the seasonal indices of a univariate time series by using classical decomposition.

Required Arguments

You must specify the following arguments, separated by commas:

y specifies the times series array to decompose.

s specifies the seasonality to test, where *s* must be either a positive integer or _SEASONALITY_, which is the length of the seasonal cycle as specified by the SEASONALITY= option in the PROC TSMODEL statement or implied by the INTERVAL= option in the ID statement.

'*mode*' specifies the type of decomposition to be used to decompose the time series.

You can specify the following values within single quotation marks:

ADD | ADDITIVE specifies additive decomposition.

LOGADD | LOGADDITIVE specifies log-additive decomposition.

MULT | MULTIPLICATIVE specifies multiplicative decomposition.

MULTORADD specifies multiplicative or additive decomposition, depending on data.

PSEUDOADD | PSEUDOADDITIVE specifies pseudo-additive decomposition.

Optional Arguments

You can also specify the following argument, separated by a comma from arguments that precede it. If you want to use a default value for this argument, enter a space for it.

lambda specifies the Hodrick-Prescott filter parameter for trend-cycle decomposition. The default value is 1,600. Filtering applies when the trend component or the cycle component is requested. If filtering is not specified, this option is ignored.

Returned Values

The SEASONALDECOMP function returns the following values:

rc returns one of the following scalar return codes:

rc	**Termination Reason**
0	Success
< 0	Computational failure

Optional Returned Values

You can also specify the following arguments, separated by commas to request additional returned values. If you do not want the value to be returned, enter a space for it.

tcc specifies the trend-cycle component.

sic specifies the seasonal-irregular component.

sc specifies the seasonal component.

scstd specifies the seasonal component standard errors.

tcs specifies the trend-cycle-seasonal component.

ic specifies the irregular component.

sa specifies the seasonally adjusted series.

pcsa specifies the percentage of change in seasonally adjusted series.

tc specifies the trend component.

cc specifies the cycle component.

Example

This example uses the TSMODEL procedure to compute the seasonal indices on the time series array Air:

```
proc tsmodel data=mycas.air outarray=mycas.outarray;
   id date interval=month;
   var air;
   outarray ADJUSTED;
   require tsa;
   submit;
   declare object TSA(tsa);
   rc=TSA.SEASONALDECOMP(air, _SEASONALITY_, 'ADD', , , , , , , , ADJUSTED, , , );
   endsubmit;
run;
```

SEASONALINDICES Function

rc = **TSA.SEASONALINDICES** *(y, s, <'mode'>, <'term'>, indices)* **;**

The SEASONALINDICES function computes the seasonal indices of a univariate time series by using regression seasonal dummies.

Required Arguments

You must specify the following arguments, separated by a comma:

y specifies the times series array.

s specifies the seasonality to test, where *s* must be either a positive integer or _SEASONALITY_, which is the length of the seasonal cycle as specified by the SEASONALITY= option in the PROC TSMODEL statement or implied by the INTERVAL= option in the ID statement.

Optional Arguments

You can also specify the following arguments, separated by commas. If you want to use a default value for any of these arguments, enter a space for it.

'*mode*' specifies the type of model to be used in the regression.

You can specify the following values within single quotation marks:

ADD | ADDITIVE uses an additive model.

MULT | MULTIPLICATIVE uses a multiplicative model.

The default method is ADD.

'*term*' specifies the type of terms to be used in the regression.

You can specify the following values within single quotation marks:

S uses only seasonal dummies terms.

SC uses only seasonal dummies and constant terms.

ST uses only seasonal dummies and trend terms.

STC uses seasonal dummies, trend, and constant terms.

STQ uses seasonal dummies, trend, and quadratic terms.

STQC uses seasonal dummies, trend, quadratic, and constant terms.

The default value is S. Quadratic values can be used only in the additive model.

Returned Values

The SEASONALINDICES function returns the following values:

rc returns one of the following scalar return codes:

rc	**Termination Reason**
0	Success
< 0	Computational failure

indices returns an array of seasonal indices.

Example

This example uses the TSMODEL procedure to compute the seasonal indices of the time series Air:

```
proc tsmodel data=mycas.air outarray=mycas.outarray;
   id date interval=month;
   var air;
   outarrays sindices;
   require tsa;
   submit;
   declare object TSA(tsa);
   rc=TSA.SEASONALINDICES(air, _SEASONALITY_,  'ADD', 'STQC', sindices);
   endsubmit;
run;
```

SEASONTEST Function

rc = **TSA.SEASONTEST** *(y, s, < dif >, < p >, < alpha >, < aic >)* **;**

The SEASONTEST function tests whether a univariate time series is seasonal by comparing two time series models: one seasonal and one nonseasonal.

Required Arguments

You must specify the following arguments, separated by a comma:

y specifies the times series array to test.

s specifies the seasonality to test, where *s* must be either a positive integer or _SEASONALITY_, which is the length of the seasonal cycle as specified by the SEASONALITY= option in the PROC TSMODEL statement or implied by the INTERVAL= option in the ID statement.

Optional Arguments

You can also specify the following arguments, separated by commas. If you want to use a default value for any of these arguments, enter a space for it.

dif specifies an array of positive integers or a positive integer that is used for differencing. The default value is 0.

p specifies the autoregressive order (0 or 1). The default value is 0.

alpha specifies the significance level. The default value is 0.01.

Returned Values

The SEASONTEST function returns the following values:

rc returns one of the following scalar return codes:

rc	**Termination Reason**
0	Time series is not seasonal
1	Time series is seasonal
< 0	Computational failure

Optional Returned Values

You can also specify the following arguments, separated by commas to request additional returned values. If you do not want the value to be returned, enter a space for it.

aic returns an array of three values: Akaike's information criterion (AIC) for the nonseasonal model, AIC for seasonal model, and the p-value for the F test.

Example

The following example uses the TSMODEL procedure to test the seasonality of the time series array Air:

```
proc tsmodel data=mycas.air outscalars=mycas.outscalars
             outarray=mycas.outarray;
   id date interval=month;
   var air;
   outscalars seasonal;
   outarray aic;
   require tsa;
   submit;
   declare object TSA(tsa);
   seasonal=0;
   rc=TSA.SEASONTEST(air, _SEASONALITY_, 0, 1, , aic); /*- no detrending -*/
   if rc>0 then seasonal= 1;
   rc=TSA.SEASONTEST(air, _SEASONALITY_, 1, 1, 0.05, ); /*- detrending -*/
   if rc>0 then seasonal= 1;
   endsubmit;
run;
```

SIMILARITY Function

rc = **TSA.SIMILARITY** *(x, y, <'type'>, <'scale'>, <expandpct>, <expandabs>, <compresspct>, <compressabs>, measure)* **;**

The SIMILARITY function analyzes the similarity between two time series.

Required Arguments

You must specify the following arguments, separated by a comma:

x specifies the input time series array to be compared to the target time series.

y specifies the target time series array to be compared to the input time series.

Optional Arguments

You can also specify the following arguments, separated by commas. If you want to use a default value for any of these arguments, enter a space for it.

'*type*' specifies the similarity measure.

You can specify the following values within single quotation marks:

ABSDEV specifies the absolute deviation.

MABSDEV specifies the mean absolute deviation.

MABSDEVINP specifies the mean absolute deviation relative to the length of the input sequence.

MABSDEVMAX specifies the mean absolute deviation relative to the maximum valid path length.

MABSDEVMIN specifies the mean absolute deviation relative to the minimum valid path length.

MABSDEVTAR specifies the mean absolute deviation relative to the length of the target sequence.

MSQRDEV specifies the mean squared deviation.

MSQRDEVINP specifies the mean squared deviation relative to the length of the input sequence.

MSQRDEVMAX specifies the mean squared deviation relative to the maximum valid path length.

MSQRDEVMIN specifies the mean squared deviation relative to the minimum valid path length.

MSQRDEVTAR specifies the mean squared deviation relative to the length of the target sequence.

SQRDEV specifies the squared deviation.

The default value is SQRDEV.

'*scale*' specifies how the working input sequence is scaled with respect to the working target sequence. Scaling is performed after normalization.

You can specify the following values within single quotation marks:

ABS applies absolute scaling.

NONE applies no scaling.

STD applies standard scaling.

The default value is NONE.

expandpct specifies the warping expansion as a percentage of the length of the target sequence, where *expandpct* ranges from 0 to 100, 0 implies no compression, and 100 implies maximum allowable compression. The default value is 100.

expandabs specifies the absolute warping expansion, where *expandabs* is an integer that ranges from 0 to 10,000. The default is the maximum allowable absolute expansion.

compresspct specifies the warping compression as a percentage of the length of the target sequence, where *compresspct* ranges from 0 to 100, 0 implies no compression, and 100 implies maximum allowable compression. The default value is 100.

compressabs specifies the absolute warping compression, where *compressabs* is an integer that ranges from 0 to 10,000. The default is the maximum allowable absolute compression.

Returned Values

The SIMILARITY function returns the following values:

rc returns one of the following scalar return codes:

rc	**Termination Reason**
4	Warping limits relaxed
3	Expansion limits relaxed
2	Compression limits relaxed
1	Warping limits imposed
0	Success
< 0	Computational failure

measure returns the similarity measure.

Example

This example uses the TSMODEL procedure to compute the similarity of two time series arrays: x and y.

```
data test;
   input i y x;
datalines;
1   2  3
2   4  5
3   6  3
4   7  3
5   3  3
6   8  6
7   9  3
8   3  8
9  10  .
10 11  .
;

data test;
   input i x1 x2 x3 y1 y2 y3 r;
datalines;
1  3 2 4 2 3  2   1
2  5 4 5 4 5  3   1
3  3 3 4 6 4  5   1
4  3 6 6 7 6  7   1
5  3 5 5 3 5  7   1
6  6 6 6 8 8  8   1
7  3 8 5 9 9  8   1
8  8 9 8 3 7  3   1
9  6 7 6 8 4  9   1
10 7 9 8 9 6  7   1

;
run;

data mycas.testsim;
   set test;
run;
proc tsmodel data=mycas.testsim outscalars=mycas.tsa_scalar2;
   require tsa;
   submit;
   declare object TSA(tsa);
   var x y;
   outscalar measure;
   rc=TSA.SIMILARITY(x, y, 'ABSDEV', 'NONE', 20, 0 , , , measure);
   endsubmit;
run;
```

STATIONARITYTEST Function

rc = **TSA.STATIONARITYTEST** *(y, < dif >, < d >, < p >, < 'type' >, pvalue)* **;**

The STATIONARITYTEST function tests for stationarity of a univariate time series.

Required Arguments

You must specify the following argument:

y specifies the times series array to test.

Optional Arguments

You can also specify the following arguments, separated by commas. If you want to use a default value for any of these arguments, enter a space for it.

dif specifies an array of positive integers or a positive integer that is used for differencing. The default value is 0.

d specifies the order of unit root ($d = 1, \ldots, 12$). If the *type* is SSM, then $d = 1$. The default value is 1.

p specifies the autoregressive order, where *p* must be a nonnegative integer. The default value is 5.

'*type*' specifies the type of test statistic used.

You can specify the following values within single quotation marks:

SSM specifies the studentized test statistic for the single mean (intercept) case.

STR specifies the studentized test statistic for the deterministic time trend case.

SZM specifies the studentized test statistic for the zero mean (no intercept) case. This value is allowed only when *d*=1.

The default value of *type* is SZM.

Returned Values

The STATIONARITYTEST function returns the following values:

rc returns one of the following scalar return codes:

rc	**Termination Reason**
0	Time series is stationary with the default significance level of 0.05
1	Time series is not stationary with the default significance level of 0.05
< 0	Computational failure

pvalue returns the probability value associated with the test.

Example

This example uses the TSMODEL procedure to test the stationarity on the time series array Air:

```
proc tsmodel data=mycas.air outscalars=mycas.outscalars;
   id date interval=month;
   var air;
   outscalars stationary1 stationary2;
   require tsa;
   submit;
   declare object TSA(tsa);
   stationary1=1; stationary2=1;
   rc = TSA.STATIONARITYTEST(air,,,,,pvalue);
   *test with the default significant level=0.05;
   if rc =1 then stationary1 = 0;
   *test with significant level = 0.1;
   if pvalue > 0.1 then stationary2 = 0;
   endsubmit;
run;
```

TRANSFORM Function

rc = **TSA.TRANSFORM** *(y, <'type'>, <inverse>, <c>, x)* **;**

The TRANSFORM function transforms a time series to another form.

Required Arguments

You must specify the following arguments:

y specifies an input time series array.

Optional Arguments

You can also specify the following arguments, separated by commas. If you want to use a default value for any of these arguments, enter a space for it.

type specifies the type of transformation. You can specify the following values within single quotation marks:

LOG specifies logarithmic transformation.

SQRT specifies square root transformation.

LOGIT specifies logit transformation.

BOXCOX specifies Box-Cox transformation.

NONE requests that no transformation be performed.

The default value is NONE.

inverse specifies whether to perform an inverse transformation. You can specify the following values:

0 does not perform an inverse transformation.

1 returns the inverse of the specified transformation method.

The default value is 0.

c specifies a parameter to be used in the transformation. Its use depends on the transformation method as follows:

- For log transformation, c is bias: $x = \log(y + c)$. The default value is 0.
- For square root transformation, c is bias: $x = \log(y + c)$. The default value is 0.
- For logit transformation, c is scaling: $x = \log(c \times y/(1 - (c \times y)))$. The default value is 1.
- For the Box-Cox transformation, c is λ: $x = c^2 + (y^c - 1)/c$. If c is not specified, x=y.

Returned Values

The TRANSFORM function returns the following values:

rc returns one of the following scalar return codes:

rc	**Termination Reason**
0	Success
< 0	Computational failure

x returns the transformed series.

Example

This example uses the TSMODEL procedure to take the log transform of the time series array Air:

```
proc tsmodel data=mycas.air outarray=mycas.trans_array;
   var air;
   require tsa;
   submit;
   declare object TSA(tsa);
   outarrays t1;
   rc=TSA.TRANSFORM(air, 'LOG', 0, 0, t1);
   endsubmit;
run;
```

UNBIASEDNESS Function

rc = **TSA.UNBIASEDNESS** *(y, predict, < siglevel >, intercept, scale, fvalue, pvalue)* **;**

The UNBIASEDNESS function tests whether a univariate time series is unbiased.

Required Arguments

You must specify the following arguments, separated by a comma:

y specifies the input time series array.

predict specifies an input array of predicted time series.

Optional Arguments

You can also specify the following argument. If you want to use a default value for this argument, enter a space for it.

siglevel specifies the significance level.

Returned Values

The UNBIASEDNESS function returns the following values:

rc returns one of the following scalar return codes:

rc	**Termination Reason**
1	Biased predictions
0	Unbiased predictions
–1	Degree of freedom error
–2	Singular system
–3	Extreme value

intercept returns the constant parameter.

scale returns the scale parameter.

fvalue returns the test statistic for the F test.

pvalue returns the p-value for the F test.

Example

This example uses the TSMODEL procedure to test whether the series Actual is unbiased:

```
proc hpf data=sashelp.air out=_null_ outfor=outfor;
   id date interval=month;
   forecast air;
run;

proc reg data=outfor;
   model actual=predict;
   test intercept=0, predict=1;
run;
quit;
data mycas.outfor;
   set outfor;
run;

proc tsmodel data=mycas.outfor outscalars=mycas.bias_scalar outarray=mycas.bias_array;
   id date interval=month;
   var ACTUAL PREDICT;
   outscalars intercept scale fvalue pvalue;
   require tsa;
   submit;
   declare object TSA(tsa);
   rc=TSA.UNBIASEDNESS(ACTUAL, PREDICT, 0.05, intercept, scale, fvalue, pvalue);
   endsubmit;
run;
```

WHITENOISE Function

rc **= TSA.WHITENOISE** *(y, nlag, lags, df, wn, < wnprob >, < wnlprob >)* **;**

The WHITENOISE function tests for white noise in a time series array.

Required Arguments

You must specify the following arguments, separated by a comma:

y specifies the times series array to compute.

nlag specifies the number of the lag to use in the calculation.

Returned Values

The WHITENOISE function returns the following values:

rc returns one of the following scalar return codes:

rc	**Termination Reason**
0	Success
< 0	Computational failure

lags returns the number of the lag that was used in the calculation.

df returns the number of observations that were used to test white noise.

wn returns an array of Ljung-Box white noise tests, with *nlag*+1 entries.

Optional Returned Values

You can also specify the following arguments, separated by commas to request additional returned values. If you do not want the value to be returned, enter a space for it.

wnprob returns white noise probabilities.

wnlprob returns white noise log probabilities.

Example

This example uses the TSMODEL procedure to perform the white noise test of lag 3 of the time series Air:

```
proc tsmodel data=mycas.air outarray=mycas.outarray;
   id date interval=month;
   var air;
   outarrays lags df wn wnprob wnlprob;
   require tsa;
   submit;
   declare object TSA(tsa);
   rc=TSA.WHITENOISE(air, 3, lags, df, wn, wnprob, wnlprob);
   endsubmit;
run;
```

Chapter 5
Time Series Model Package for the TSMODEL Procedure

Contents

Overview

The time series model (TSM) package contains a set of time series modeling objects that provide a flexible way to model and forecast time series. For more information about the statistical methodology that underlies this package, see relevant chapters in *SAS/ETS User's Guide* and *SAS Forecast Server Procedures: User's Guide*. This document describes the following objects, which are contained in the TSM package and designed to provide access to various univariate time series model families:

- The TSM object is the central hub that interacts with all other objects. It executes and encapsulates the computational services for all univariate time series models.
- The following time series model specification objects enable you to specify the characteristics of a time series model to be executed by a TSM object:
  - ESMSpec (exponential smoothing model specification)
  - ARIMASpec (autoregressive integrated moving average specification)
- The following time series model collector objects operate on TSM objects to collect and save various results from the time series model execution (fit statistics, forecasts, parameter estimates, model specifications, and so on):
  - TSMPEst (time series model parameter estimates collector)
  - TSMSpec (time series model specification collector)
  - TSMFor (time series model forecast collector)
- The following time series model repeater objects act as conduits to replay collected model specifications and model parameter estimates as input to other TSM objects:
  - TSMINEst (time series model input parameter estimates repeater)
  - TSMINSpec (time series model input specification repeater)

TSM Package Summary

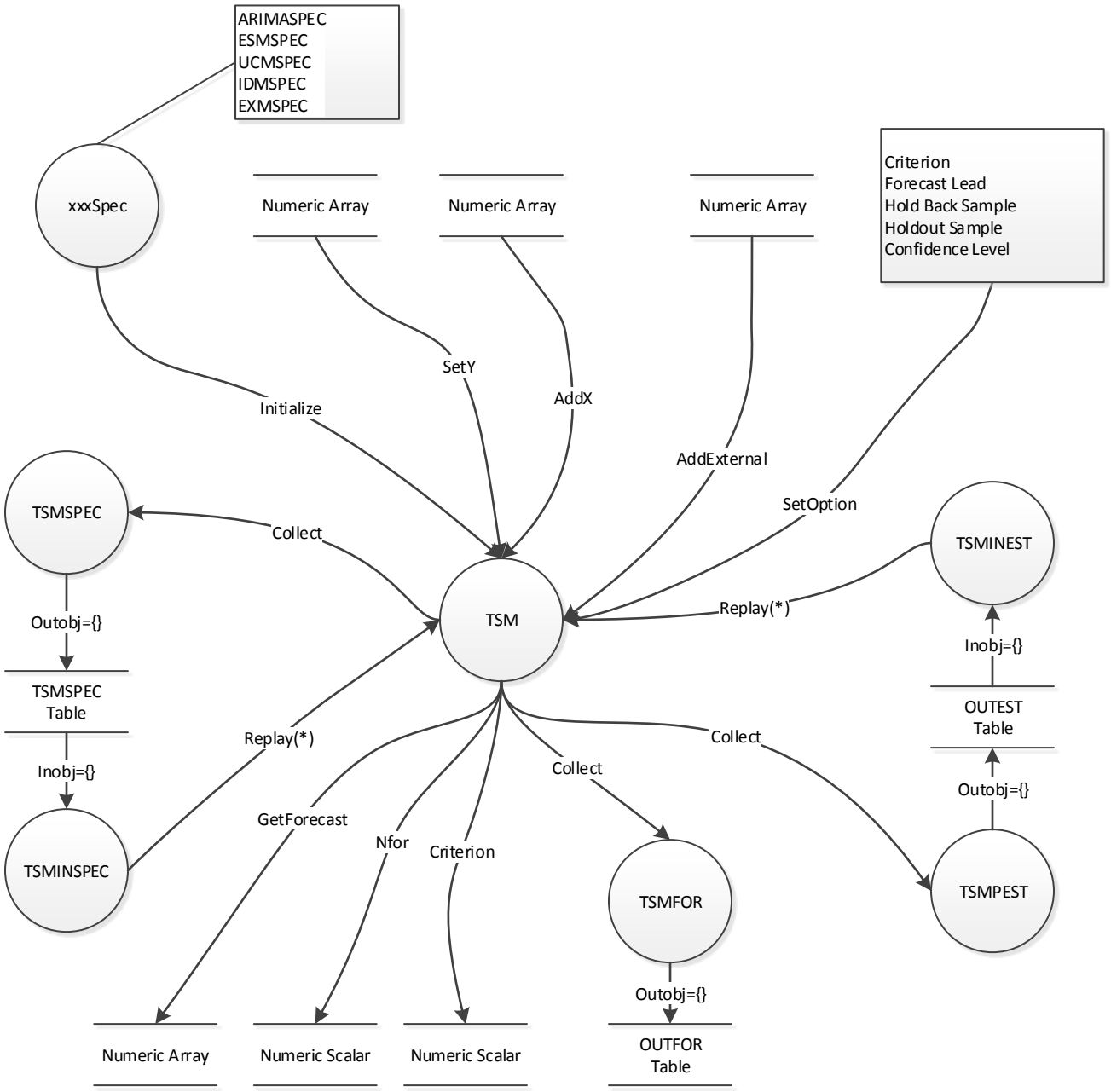
All of the objects in the TSM package are summarized in Table 5.1.

Table 5.1 Objects in Time Series Model Package

TSM Function	Description
TSM	Time series model object
ESMSpec	Exponential smoothing model specification object
ARIMASpec	Autoregressive integrated moving average model specification object
TSMPEst	Time series model parameter estimates collector object
TSMSpec	Time series model specification collector object
TSMFor	Time series model forecast collector object
TSMINEst	Time series model input parameter estimates repeater object
TSMINSpec	Time series model input specification repeater object

The data flow between the TSM objects is illustrated in Figure 5.1.

Figure 5.1 TSM Object Data flow



Using the TSM Package

The following steps provide a general outline of how to use each type of object in the TSM package. Subsequent sections describe each step in greater detail.

1. Configure a model specification object.
2. Use a TSM object with the model specification object to generate a forecast.
3. Use TSM collector objects to extract results and parameter estimates from the TSM object.
4. Use TSM repeater objects to replay collected parameters and specifications to another TSM object.

Step1: Configure a Model Specification Object

Model specification objects are used to define the time series model characteristics that you want to be applied to the TSM object, which then performs the model execution. Model specification objects use **Open( )** and **Close( )** methods to initialize and finalize model specifications. The basic execution pattern follows this sequence of operations:

1. **Declare:** Create the model specification object by using the object declaration statement. The object declaration assigns a default model specification to the specification objects.
2. **Open:** Initialize the specification object to a default state that is ready to accept configuration methods that shape the model and define its characteristics.
3. **Configure:** Use model specification object-specific methods to configure the model. For example, in an ESMSpec, you might specify the smoothing method or model to be used, specify a functional transformation for the dependent variable to force the use of specific smoothing parameters, or specify bounds on the estimated parameters. For an ARIMASpec, you might specify a set of AR or MA backshift operator polynomial factors, specify differencing operators, add simple and complex transfer functions, or specify a functional transformation for the dependent variable.
4. **Close:** Declare the model specification object to be complete and ready for use.
5. **Use:** Use the completed model specification object with a TSM object to directly perform the specified time series model fit and forecast computations. You can also use model specification objects with the automatic time series modeling (ATSM) package to include custom models into its automatic time series forecasting process. For more information on this use, see Chapter 1, "Automatic Time Series Analysis and Forecasting Package for the TSMODEL Procedure."

Step2: Use a TSM Object with a Model Specification Object

The TSM object executes the time series model. The TSM object is configured with a time series model from one of the model specification objects. Then the TSM object applies that configuration to the time series data to produce a forecast. The basic execution pattern follows this sequence of operations:

1. **Declare:** Create the TSM object by using the object declaration statement.
2. **Initialize:** Add a model specification object to the TSM object.
3. **Specify Variables:** Specify the dependent (Y) series and any independent (X) series variables.
4. **Specify Options:** Specify other options and properties as appropriate.
5. **Run:** Execute the model in the TSM object to produce its forecast.
6. **Extract:** Extract the results by using collector objects.

Various properties (attributes) of the completed TSM object can be queried directly and saved into declared variables, or the results can be collected by the TSM collector objects for presentation and storage as desired.

Step3: Use the TSM Collector Objects

Collector objects enable you to create a snapshot of results from TSM objects and store them to CAS tables. Each collector object defines a table schema that is determined by the collector object's design. The TSM collector objects follow a common method pattern. The basic execution follows this sequence of operations:

1. **Declare:** Create the collector object using the object declaration statement.
2. **Collect:** Use the Collect method with a TSM object passed as an argument to collects results from the TSM object. For example, the TSMPEst object collects parameter estimates from a TSM object, and the TSMSpec object collects from a model specification's XML. Rows that are collected are automatically appended to the collector's associated CAS table at the end of each BY group, and the collector object's saved row set is automatically reset. Rows that are added to the CAS table are qualified by the corresponding BY variable values. The **nrows** attribute returns the current row count in the collector. A missing value is returned if nothing has been collected. The data can now be used for reports or used by a repeater object on another model.

Step 4: Use the TSM Repeater Objects

Repeater objects restore rows from a CAS table to make them available for use by other TSM objects. This is the inverse function of the collector objects. Each repeater object defines a CAS table schema that is determined by the repeater object's design. Repeater objects must be bound to an existing CAS table that has the table schema that is required by the repeater object. The basic execution follows this sequence of events:

1. **Declare:** Create the repeater object by using the object declaration statement.
2. **Replay:** Use the TSM.replay method on a TSM object with the repeater object and CAS table passed as arguments to execute a new time series model. The data can then be collected by using a collector object as described in step 3.

Status Codes

Status return codes (designated *rc* in method usage statements) are numeric values that are returned when a method associated with an object is called; they are defined in Table 5.2. These codes can help determine whether the method executed successfully.

Table 5.2 Status Codes

Status	Meaning
Status < 0	An unrecoverable error occurred. No result was produced.
Status = 0	Unconditional success. The requested action was completed, and a normal result was produced.
Status > 0	Conditional success or warning. A result was produced subject to conditions.

TSM Object Summary

The time series model (TSM) object generates forecasts of univariate time series. Table 5.3 lists the time series model families that are supported.

Table 5.3 TSM Model Families

Family	Specification Object	Description
ESM	ESMSpec	Exponential smoothing models
ARIMA	ARIMASpec	ARIMAX models

The basic execution pattern for using a TSM object follows this sequence of operations:

1. **Declare:** The object declaration statement creates a new TSM object.
2. **Initialize:** The TSM.Initialize method takes a model specification object as its argument and initializes the TSM object for that specified time series model. If no model specification object is provided, the TSM object is initialized by the default ESM specification.
3. **SetY:** The TSM.SetY method defines the dependent time series for the TSM object.
4. **AddX:** The TSM.AddX method defines any independent time series for the TSM object. Each call defines one predictor series. Repeat as needed for each series.
5. **SetOption:** The TSM.SetOption method specifies any options that affect the running of the model. Each call defines an option. Repeat as needed to specify all options that are required.

6 **Run:** The TSM.run method uses its currently configured X and Y time series data to execute the time series model that is defined by the TSM object's model specification. At completion, the model has estimated the parameters and produced a final forecast based on these parameters.

TSM Synopsis

The object declaration statement creates a new object, *obj*, of type **TSM**.

DECLARE OBJECT *obj* (**TSM**) **;**

Upon declaration, the TSM objects have a default model—ESM/method=BEST. Table 5.4 summarizes the methods and attributes that are associated with the TSM Object.

Table 5.4 Methods of the TSM Object

TSM Method	Description
Initialize	Initialize the TSM object.
SetY	Specify the dependent time series array (Y) for the TSM object.
AddX	Add an independent time series array (XSeries) for the TSM object.
SetOption	Specify the named option for the TSM object
Run	Run the TSM object.
Replay	Replay the restored model and parameter estimates.
GetForecast	Get the forecast series.
NFor	Return the forecast series length.
Criterion	Create the final forecast fit statistic.

TSM Methods

This section describes the methods of a TSM object.

TSM.Initialize Method

The Initialize method initializes a TSM object to use the specified *ModelSpec*. This method must be called before specifying the time series arrays (X and Y series) and other attributes for the TSM object. If no ModelSpec object is specified, the TSM object is initialized to use the default ESM specification.

Usage: *rc* **=** *obj*.**Initialize** (< *ModelSpec* >) **;**

Parameters

[in] **ModelSpec** Optional name of a TSM model specification object that is used to configure the TSM object.

TSM.SetY Method

The SetY method specifies the dependent time series array, *YSeries*, for the TSM object.

Usage: *rc* **=** *obj***.SetY** *(YSeries)* **;**

Parameters

[in] **YSeries** Numeric array that contains the dependent series for the TSM object.

TSM.AddX Method

The AddX method adds an independent time series array, *XSeries*, for the TSM object. Each call to the AddX method adds the specified X variable to the TSM object. This method can be called as many times as needed to specify all the independent variables. By default, the name of the *XSeries* variable must match the name of an input symbol in the model specification that is used to configure the TSM object. You can specify a symbol name, *ModelSymbol*, to associate an *XSeries* array to an input symbol in the model specification. Only ARIMA models support *XSeries* predictors.

Usage: *rc* **=** *obj***.AddX** *(XSeries < , Required, NoDiff, ModelSymbol >)* **;**

Parameters

[in] **XSeries** Numeric array that specifies an independent series for the TSM object.

[in] **Required** Optional binary variable (0 or 1). A value of 1 specifies that the X-variable is required to be in the model. This might cause the model estimation to fail if it is deemed inadmissible for inclusion into the underlying ARIMA model. The default value is 0.

[in] **NoDiff** Optional numeric variable (0 or 1). A value of 1 specifies that the X-variable does not automatically follow the Y-variable differencing. The default value is 0.

[in] **ModelSymbol** Optional character variable that specifies the name of an input symbol in the model specification to be bound to the X variable when the model is run. By default, TSM.AddX adds X variables into an ARIMAmodel specification if they are not already referenced as an input symbol. Specification of ModelSymbol defines a way to include the X variable if the ARIMASpec object includes a symbol that matches the ModelSymbol argument.

TSM.SetOption Method

The SetOption method specifies named options for the TSM object. *Name* is a character literal or variable. The type of *Value* depends on the value of *Name*. Table 5.5 shows the allowed options.

Usage: *rc* **=** *obj***.SetOption** *('Name', Value < , 'Name', Value,... >)* **;**

Table 5.5 '*Name*' Arguments for the TSM.SetOption Method

'Name'	Value Type	Value
CRITERION	String	Fit statistic mnemonic. For more information, see the CRITERION= option in the PROC HPFDIAGNOSE statement in the HPFDIAGNOSE chapter in *SAS Forecast Server Procedures: User's Guide*
LEAD	Numeric	Forecast lead (nonnegative integer)
BACK	Numeric	BACK region (nonnegative integer)
HOLDOUT	Numeric	HOLDOUT region (nonnegative integer)
ALPHA	Numeric	CI band significance level ($0 \leq$ *Value* ≤ 1)

Parameters

[in] **Name** Character variable that names the option to specify.

[in] **Value** Specifies the value for the named option.

TSM.Replay Method

The Replay method enables the restoration of a previously saved model specification from a *TSMINSpecObj* as input to another TSM object. Optionally, restored parameter estimates from *TSMINEstObj* are applied to the model specification.

Usage: *rc* **=** *obj*.**Replay** *(TSMINSpecObj* < *, TSMINEstObj* > *)* **;**

Parameters

[in] **TSMINSpecObj** Object to supply the model specification.

[in] **TSMINEstObj** Optional object to supply the model's parameter estimates.

TSM.Run Method

The Run method runs the TSM object to estimate and forecast the time series model by using the dependent (Y) and independent (X) series that have been specified for it. Upon successful completion, various results can be extracted from the TSM object.

Usage: *rc* **=** *obj*.**Run** *( )* **;**

Parameters

No parameters are associated with this method.

TSM.GetForecast Method

The GetForecast method places the specified forecast series, '*Which*', from the TSM object into the specified numeric array, *Result*.

Usage: *rc* = *obj*.**GetForecast** *('Which', Result)* **;**

Parameters

[in] **Which** Character string whose value specifies the forecast series to return. Supported series are described in Table 5.6.

[out] **Result** Numeric array to receive the forecast series.

Table 5.6 'Which' Arguments for the TSM.GetForecast Method

Which	Meaning
PREDICT	Forecast series
ERROR	Residual series
STDERR	Forecast standard error series
UPPER	Upper confidence limit series
LOWER	Lower confidence limit series

TSM Attributes

This section describes TSM methods that return some useful attributes of the TSM object.

TSM.NFor Method

The NFor method returns the length (number of observations) of the forecast series for the TSM object. A missing value indicates that the TSM object has not produced a successful forecast.

Usage: *nfor* = **obj.nfor** *( )* **;**

TSM.Criterion Method

The Criterion method returns the fit statistic value for the final forecast for the TSM object. The criterion is specified via TSM.SetOption method. A missing value indicates that the TSM object has not produced a successful forecast.

Usage: *criterion* = **obj.criterion** *( )* **;**

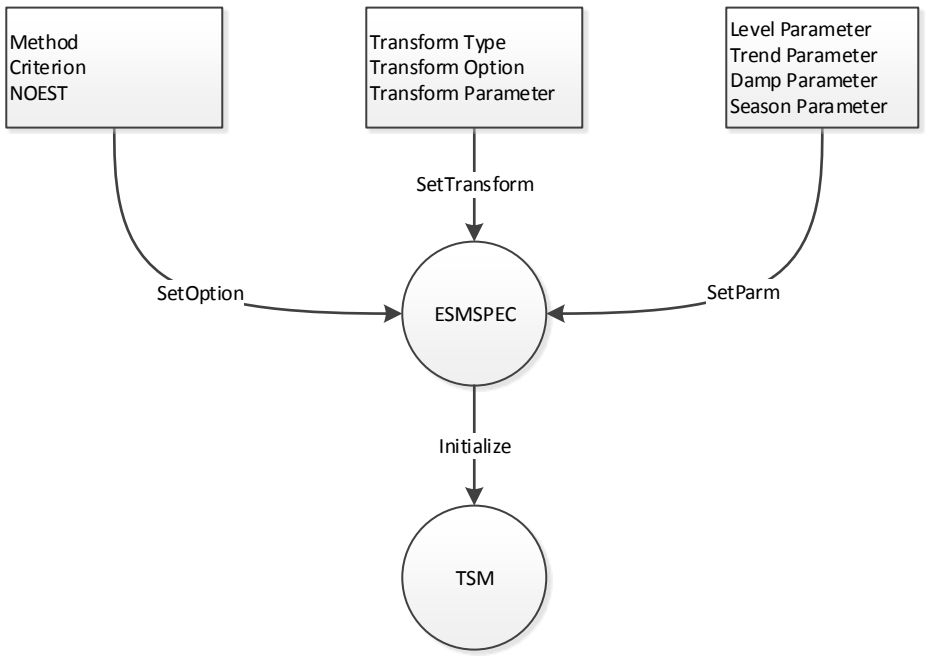
ESMSpec Object Summary

The ESMSpec object defines an exponential smoothing model specification for use with the TSM object. The basic execution pattern for defining an ESMSpec follows this sequence of operations:

1. **Declare:** The object declaration statement creates a new ESMSpec object. By default, it is an ESMSpec with METHOD=BEST.
2. **Open:** The ESMSpec.Open method initializes the default ESMSpec object for a new configuration.
3. **Configure:** The various ESMSpec.Set methods configure the ESMSpec object.
4. **Close:** The ESMSpec.Close method finalizes the ESMSpec object.
5. **Apply:** Add the ESMSpec to a TSM object using the TSM.Initialize method.

You can also store the XML representation of the ESMSpec to a CAS table. For more information, see the TSMSpec object. Data flow through the ESMSpec object is illustrated in Figure 5.2.

Figure 5.2 ESMSpec Object Data flow



ESMSpec Synopsis

The object declaration statement creates a new object, *obj*, of type **ESMSpec**.

DECLARE OBJECT *obj* (**ESMSpec**) **;**

Table 5.7 summarizes the methods that are associated with the ESMSpec method.

Table 5.7 Methods of the ESMSpec Object

ESMSpec Method	Description
Open	Open ESM model specification.
Close	Close ESM model specification.
SetTransform	Set transform for ESM model.
SetParm	Set parameters for ESM model.
SetOption	Set option for ESM model.

ESMSpec Methods

This section describes the methods of a ESMSpec object.

ESMSpec.Open Method

The Open method initializes the ESMSpec object for a BEST ESM model with no transformation.

Usage: *rc* **=** *obj***.Open** *( )* **;**

Parameters

There are no parameters associated with this method.

ESMSpec.Close Method

The Close method finalizes the ESMSpec object to prepare the ESM model to be used in a TSM object or to be imported to a TSMSpec object for printing or for storage in a model repository catalog.

Usage: *rc* **=** *obj***.Close** *( )* **;**

Parameters

There are no parameters associated with this method.

ESMSpec.SetTransform Method

The SetTansform method specifies the functional transform, '*Type*', to be used by the ESM model. Optional arguments *Option* and *Parm* offer greater control over the transform.

Usage: *rc* **=** *obj*.**SetTransform** ('*Type*' < , '*Option*', *Parm*>) **;**

Parameters

[in] **Type** Character string that specifies the functional transform to use. Table 5.8 describes the transformations available. The default value is NONE.

[in] **Option** Optional character string that specifies prediction semantics for the inverse transform. Values are 'MEAN' or 'MEDIAN'. The default is 'MEAN'.

[in] **Parm** Optional numeric variable that specifies a control parameter (a number between –5 and 5) for the functional transform. This parameter is allowed only for Box-Cox transforms.

Table 5.8 'Type' Arguments for ESMSpec.SetTransform

Transform	Description
NONE	No transformation
LOG	Log transformation (positive series)
AUTO	Select between NONE and LOG
SQRT	Square root transformation (nonnegative series)
LOGISTIC	Logistic transformation
BOXCOX	Box-Cox transformation ($-5 \leq$ Parm ≤ 5)

ESMSpec.SetParm Method

The SetParm method specifies parameter values and restrictions for the specified ESM model component. Optional bounds, *LRest* and *URest*, can be specified to restrict the weight value for the specified ESM component during parameter optimization. Parameter values and restrictions must be in the range from –1 to 2 to be accepted.

Usage: *rc* **=** *obj*.**SetParm** ('*CompName*', *Parm*, < *LRest*, *URest*>) **;**

Parameters

[in] **CompName** Character variable that specifies the ESM component context. Table 5.9 describes the options for 'CompName'.

[in] **Parm** Numeric variable that specifies smoothing component weight (initial or fixed).

[in] **LRest** Optional numeric variable that specifies a lower bound restriction on the smoothing weight.

[in] **URest** Optional numeric variable that specifies an upper bound restriction on the smoothing weight.

Table 5.9 '*CompName*' Arguments for ESMSpec.SetParm

CompName	Description
Level	Level-state smoothing weight
Trend	Trend-state smoothing weight
Damp	Trend-state damping weight
Season	Seasonal-states smoothing weight

ESMSpec.SetOption Method

The SetOption method specifies ESM options. Options are ('*Name*',*Value*) pairs where '*Name*' is a case-insensitive character string and *Value* is dependent on the named option.

Usage: *rc* = *obj*.**SetOption** ('*Name*', *Value* < , '*Name*', *Value, ...* >) ;

Parameters

[in] **Name** Character variable that specifies the ESM option name. Table 5.10 lists valid option names and corresponding value description. Default values are in parentheses.

[in] **Value** Variable that specifies the option value.

Table 5.10 '*Name*' Arguments for ESMSpec.SetOption Method

Name	Type	Description
METHOD	String	Smoothing method (SIMPLE)
CRITERION	String	Fit statistic mnemonic (RMSE)
NOEST	Numeric	No parameter estimation (0)

Notes:

1. Values for the METHOD option include:
   - SIMPLE
   - LINEAR
   - DAMPTREND
   - WINTERS
   - ADDWINTERS
   - SEASONAL
   - MULTISEASONAL
   - BESTN
   - BESTS
   - BEST
2. See the CRITERION= option in the PROC HPFDIAGNOSE statement in the HPFDIAGNOSE chapter in *SAS Forecast Server Procedures: User's Guide*. CRITERION applies only to the ESM uber models BEST, BESTN, and BESTS.
3. NOEST requires that all parameters for the associated ESM method be explicitly specified; otherwise, it is silently ignored.

ARIMASpec Object Summary

The ARIMASpec object generates autoregressive integrated moving average (ARIMA) model specifications for use with a TSM object. The basic execution pattern for using an ARIMASpec object follows this sequence of operations:

1 **Declare:** The object declaration statement creates a new ARIMASpec object. At creation, its default state is ARIMA(0,1,0) with intercept (random walk with drift).

2 **Open:** The ARIMASpec.Open method readies the default ARIMASpec object for new configuration.

3 **Configure:** The various ARIMASpec.Set methods configure the ARIMASpec object.

4 **Close:** The ARIMASpec.Close method finalizes the ARIMASpec object.

5 **Apply:** Add the ARIMASpec to a TSM object using the TSM.Initialize method.

You can also store the XML representation of the ARIMA model to a CAS table. For more information, see the TSMSpec object. Data flow through the ARIMASpec object is illustrated in Figure 5.3

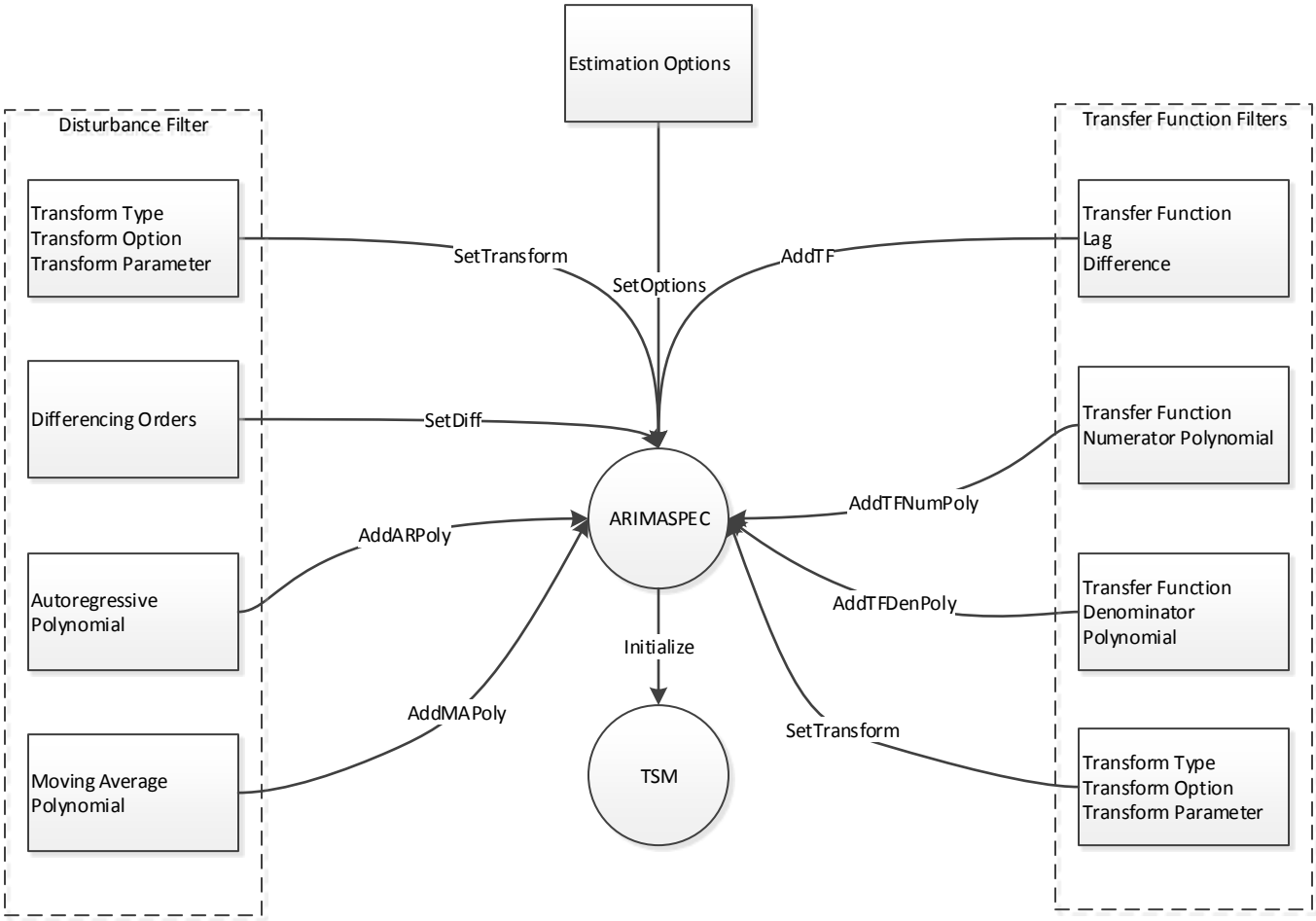
You can include series transforms such as log or Box-Cox in the specification. Deferred seasonality wildcards for seasonal ARIMA polynomial factors and seasonal differencing lags are also supported. The following notes summarize where these features can be used. More details can be found in the method descriptions.

1. ARIMASpec.SetDiff supports a seasonal wildcard lag in the DiffArray.
2. ARIMASpec.AddARPoly and ARIMASpec.AddMAPoly support addition of seasonal ARIMA polynomial factors.
3. ARIMASpec.AddTF supports a seasonal wildcard lag in the DiffArray.
4. ARIMASpec.AddTFNumPoly and ARIMASpec.AddTFDenPoly support addition of seasonal ARIMA polynomial factors for transfer function numerator and denominator, respectively.
5. ARIMASpec.SetTransform applies transforms such as log, square root, logistic, or Box-Cox to the model.

When you specify ARIMA model coefficient values for any model components, you must specify them for all without regard to the NOEST option setting. Failing to specify a complete set of ARIMA model parameters results in an error when you call ARIMASpec.Close( ), and the accumulated ARIMA model specification is reset.

Orders specified for differencing and polynomial factors must be integers greater than or equal to 1.

Figure 5.3 ARIMASpec Object Data flow



ARIMASpec Synopsis

The object declaration statement creates a new object, *obj*, of type **ARIMASpec**.

DECLARE OBJECT *obj* (**ARIMASpec**) **;**

Table 5.11 summarizes the methods that are associated with the ARIMASpec method.

Table 5.11 Methods of the ARIMASpec Object

ARIMASpec Method	Description
Open	Open ARIMA model specification.
Close	Close ARIMA model specification.
SetTransform	Specify transform.
SetDiff	Add differencing to the ARIMA model.
AddARPoly	Add autoregressive polynomial factor to the ARIMA model.
AddMAPoly	Add moving average polynomial factor to the ARIMA model.
AddTF	Add transfer function to the ARIMA model.
AddTFNumPoly	Add transfer function numerator factors to the ARIMA model.
AddTFDenPoly	Add transfer function denominator factors to the ARIMA model.
SetTFTransform	Specify the transfer function transform.
SetOption	Specify the ARIMA option.

ARIMASpec Methods

This section describes the methods of a ARIMASpec object.

ARIMASpec.Open Method

The Open method initializes an empty ARIMASpec object for configuration.

Usage: *rc* **=** *obj*.**Open** *( )* **;**

Parameters

There are no parameters associated with this method.

ARIMASpec.Close Method

The Close method finalizes the ARIMASpec object to prepare the ARIMA model to be used in a TSM object or to be imported to a TSMSpec object for printing or for storage in a model repository catalog.

Usage: *rc* = *obj*.**Close** ( ) ;

Parameters

There are no parameters associated with this method.

ARIMASpec.SetTransform Method

The SetTransform method specifies the functional transform '*Type*' to be used by the ARIMA model. Optional arguments *Option* and *Parm* offer greater control over the transform.

Usage: *rc* = *obj*.**SetTransform** ('*Type*' < , '*Option*', *Parm* >) ;

Parameters

[in] **Type** Character string that specifies the functional transform to use. Table 5.12 describes the transformations available. The default value is NONE.

[in] **Option** Optional character string that specifies prediction semantics for the inverse transform. Values are 'MEAN' or 'MEDIAN'. The default is 'MEAN'.

[in] **Parm** Optional numeric variable that specifies a control parameter (a number between –5 and 5) for the functional transform. This parameter is allowed only for Box-Cox transforms.

Table 5.12 'Type' Arguments for ARIMASpec.SetTransform

Transform	Description
NONE	No transformation
LOG	Log transformation (positive series)
SQRT	Square root transformation (nonnegative series)
LOGISTIC	Logistic transformation
BOXCOX	Box-Cox transformation ($-5 \leq$ Parm ≤ 5)

ARIMASpec.SetDiff Method

The SetDiff method adds differencing to the ARIMA model.

Usage: *rc* = *obj*.**SetDiff** (*DiffArray* < , *NDiff* >) ;

Parameters

[in] **DiffArray** Numeric array that specifies differencing orders, which must be an integer greater than or equal to 1.

[in] **NDiff** Optional numeric variable that specifies the number of DiffArray values to use. The default is to use all elements of DiffArray.

Values in DiffArray are interpreted as follows:

- Negative values are not allowed and result in an error condition.
- Nonnegative integer values represent differencing orders.
- An .S missing value is interpreted to include seasonal difference order.
- Any other missing value is ignored.

ARIMASpec.AddARPoly Method

The AddARPoly method adds an autoregressive (AR) polynomial factor to ARIMA model. Additional AR polynomial factors can be added to the ARIMA model with subsequent calls to the AddARPoly method.

Usage: *rc* **=** *obj*.**AddARPoly** *(OrderArray < , NOrder, Seasonal, CoeffArray >)* **;**

Parameters

[in] **OrderArray** Numeric array that specifies AR polynomial lags. Valid values are integers greater than or equal to 1.

[in] **NOrder** Optional numeric variable that specifies the number of OrderArray values to use. By default, all OrderArray values are used.

[in] **Seasonal** Optional numeric variable (0 or 1). A value of 1 specifies that the AR polynomial is seasonal. By default, the AR polynomial is not seasonal and the lags of the AR polynomial are simple.

[in] **CoeffArray** Optional numeric array that specifies the AR ploynomial coefficients. If specified, it must be of the same cardinality as the OrderArray.

ARIMASpec.AddMAPoly Method

The AddMAPoly method adds a moving average (MA) polynomial factor to ARIMA model. Additional MA polynomial factors can be added to the ARIMA model with subsequent calls to the AddMAPoly method.

Usage: *rc* **=** *obj*.**AddMAPoly** *(OrderArray < , NOrder, Seasonal, CoeffArray >)* **;**

Parameters

[in] **OrderArray** Numeric array that specifies MA polynomial lags, which must be greater than or equal to 1.

[in] **NOrder** Optional numeric variable that specifies the number of OrderArray values to use. By default, all OrderArray values are used.

[in] **Seasonal** Optional numeric variable (0 or 1). A value of 1 specifies that the MA polynomial is seasonal. By default, the MA polynomial is not seasonal and the lags of the MA polynomial are simple.

[in] **CoeffArray** Optional numeric array that specifies the MA ploynomial coefficients. If specified, it must be of the same cardinality as the OrderArray.

ARIMASpec.AddTF Method

The AddTF method adds a transfer function to the ARIMA model for the specified *XName* variable. This adds the variable as a simple scale effect subject to any specified lag and differencing that might be applied.

Usage: *rc* **=** *obj*.**AddTF** *(XName, < Delay, DifArray, NDiff >)* **;**

Parameters

[in] **XName** Character string that specifies the name of the X variable.

[in] **Delay** Optional numeric variable that specifies the simple delay for the predictor. If not specified, the default is 0.

[in] **DiffArray** Optional numeric array that specifies differencing orders for the X variable. Valid values are integers greater than or equal to 1. If not specified, then no differencing is applied.

[in] **NDiff** Optional numeric variable that specifies the number of DiffArray values to use. If not specified, then the size of DiffArray is assumed.

Values in DiffArray are interpreted as follows:

1. Negative values are not allowed and result in an error condition.
2. Nonnegative values represent differencing orders.
3. An .S missing value is interpreted to include seasonal difference order.
4. Any other missing value is ignored.

ARIMASpec.AddTFNumPoly Method

The AddTFNumPoly method adds a transfer function numerator polynomial factor for the specified *XName* variable. Additional polynomials can be added with subsequent calls to the AddTFNumPoly method.

Usage: *rc* **=** *obj*.**AddTFNumPoly** *(XName, NumArray < , NNum, Seasonal, CoeffArray >)* **;**

Parameters

[in] **XName** Character string that specifies the name of the X variable.

[in] **NumArray** Numeric array that specifies numerator polynomial lags for the X variable. Valid values are integers greater than 0.

[in] **NNum** Optional numeric variable that specifies the number of NumArray values to use. By default, all NumArray values are used.

[in] **Seasonal** Optional numeric variable (0 or 1). A value of 1 specifies that the numerator polynomial is seasonal. By default, the numerator polynomial is not seasonal and the lags of the numerator polynomial are simple.

[in] **CoeffArray** Optional numeric array that specifies the numerator polynomial coefficients.

ARIMASpec.AddTFDenPoly Method

The AddTFDenPoly method adds a transfer function denominator polynomial factor for the specified *XName* variable. Additional polynomials can be added with subsequent calls to the AddTFNumPoly method.

Usage: *rc* **=** *obj*.**AddTFDenPoly** *(XName, DenArray* < *, NDen, Seasonal, CoeffArray* > *)* **;**

Parameters

[in] **XName** Character string that specifies the name of the X variable.

[in] **DenArray** Numeric array that specifies denominator polynomial lags for the X variable. Valid values are integers greater than 0.

[in] **NDen** Optional numeric variable that specifies the number of DenArray values to use. By default, all DenArray values are interpreted.

[in] **Seasonal** Optional numeric variable (0 or 1). A value of 1 specifies that the denominator polynomial is seasonal. By default, the denominator polynomial is not seasonal and the lags of the denominator polynomial are simple.

[in] **CoeffArray** Optional numeric array that specifies the denominator polynomial coefficients.

ARIMASpec.SetTFTransform Method

The SetTFTransform method specifies a functional transform for specified *XName* variable.

Usage: *rc* **=** *obj*.**SetTFTransform** *(XName, 'Type',* < *Parm* > *)* **;**

Parameters

[in] **XName** Character string that specifies the name of the X variable.

[in] **Type** Character string that specifies the functional transform to use. Table 5.13 summarizes the supported transforms. The default is no transform.

[in] **Parm** Optional numeric variable that specifies a control parameter (a number between –5 and 5) for the functional transform. This parameter is used only for Box-Cox transforms.

Table 5.13 'Type' Arguments for ARIMASpec.SetTFTransform

Transform	Description
NONE	No transformation
LOG	Log transformation (positive series)
SQRT	Square root transformation (non-negative series)
LOGISTIC	Logistic transformation
BOXCOX	Box-Cox transformation ($-5 \leq Parm \leq 5$)

ARIMASpec.SetOption Method

The SetOption method specifies ARIMA model options. Options are ('*Name*',*Value*) pairs where '*Name*' is a case-insensitive character string and *Value* is dependent on the named option.

Usage: *rc* **=** *obj*.**SetOption** *(* '*Name*', *Value* < , '*Name*', *Value, ...* > *)* **;**

Parameters

[in] **Name** Character string that specifies the ARIMA option name. Table 5.14 lists valid option names and corresponding value description. Default values are in parentheses.

[in] **Value** variable that specifies the option value.

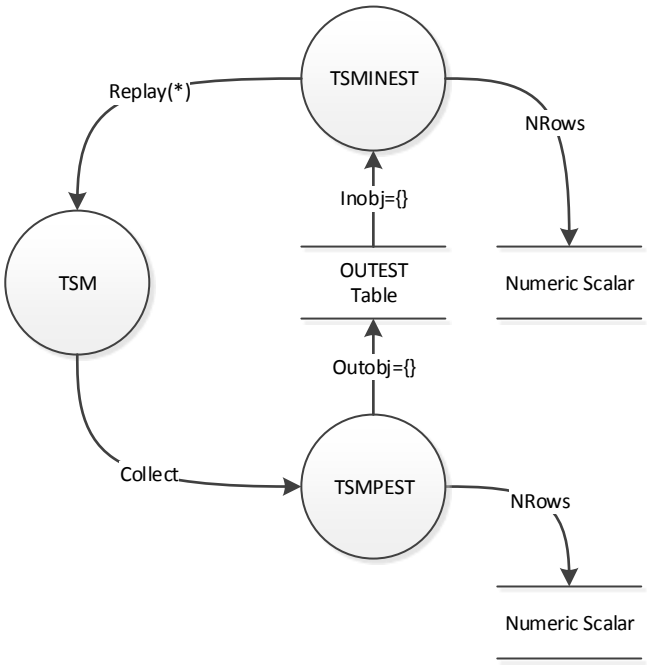
Table 5.14 'Name' Arguments for ARIMASpec.SetOption

Name	Allowed Values
CONVERGE	0 < Value < 1.0 (0.001)
DELTA	0 < Value < 1.0 (0.001)
MAXITER	Positive integer (50)
METHOD	'CLS', 'ML', 'ULS' ('CLS')
MU	Constant for ARIMA model
NOEST	0=Estimate, 1=No estimation (0)
NOINT	0=Intercept, 1=No intercept (0)
NOSTABLE	0=Check stability, 1=Do not check stability (0)
SINGULAR	0 < Value < 1.0 (1E–7)

TSMPEst Object Summary

The time series model parameter estimates (TSMPEst) collector object collects parameter estimates from a TSM object and stores them in a CAS table for printing or archiving or for use by a repeater object on another TSM object. Data flow through the TSMPEst object is illustrated in Figure 5.4

Figure 5.4 TSMPEst Object Data flow



TSMPEst Synopsis

The object declaration statement creates a new object, *obj*, of type **TSMPest**.

DECLARE OBJECT *obj* (**TSMPEst**) **;**

Table 5.15 summarizes the methods that are associated with the TSMPEst object.

Table 5.15 Methods of the TSMPEst Object

TSMPEst Method	Description
Collect	Collects parameter estimates from TSM objects.
nrows	Returns the number of rows that are collected.

TSMPEst Methods

This section describes the methods of a TSMPEst object.

TSMPEst.Collect Method

The Collect method collects time series model parameter estimates from a TSM object, *TSMObj*, and stores them in a CAS table.

Usage: *rc* **=** *obj*.**Collect** *(TSMObj)* **;**

Parameters

[in] **TSMObj**	The TSM object to use as the source of time series model parameter estimates.

TSMPEst.Nrows Attribute

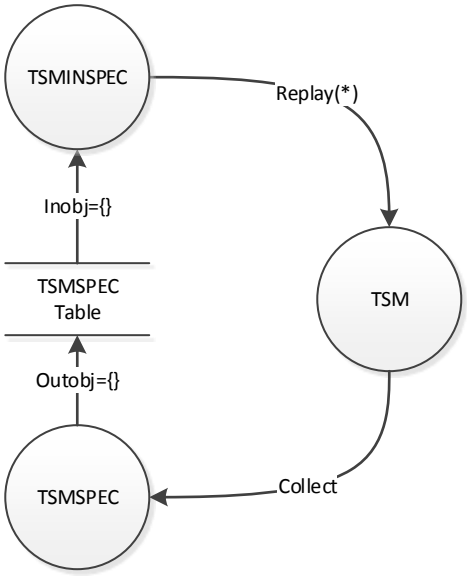
The Nrows attribute returns the number of rows that have been collected and stored in the CAS table.

Usage: *nrows* **=** *obj*.**nrows** *( )* **;**

TSMSpec Object Summary

The time series model specification (TSMSpec) collector object collects the model specification from a TSM object, *TSMObj*, and stores it in a CAS table for printing or archiving or for use by a repeater object on another TSM object. Data flow through the TSMSpec object is illustrated in Figure 5.5

Figure 5.5 TSMSpec Object Data flow



TSMSpec Synopsis

The object declaration statement creates a new object, *obj*, of type **TSMSpec**.

DECLARE OBJECT *obj* *(***TSMSpec***)* **;**

Table 5.16 summarizes the methods of the TSMSpec object:

Table 5.16 Methods of the TSMSpec Object

TSMSpec Method	Description
Collect	Collects model specification from TSM objects.

TSMSpec Methods

This section describes the methods of a TSMSpec object.

TSMSpec.Collect Method

The Collect method collects time series model specifications from a TSM object, *TSMObj*, and stores them in a CAS table.

Usage: *rc* **=** *obj***.Collect** *(TSMObj)* **;**

Parameters

[in] **TSMObj** The TSM object to use as the source of time series model specification.

TSMFor Object Summary

The Time Series Model Forecast (TSMFor) collector object collects forecast series from a TSM object, *TSMObj*, and stores them in a CAS table. The CAS table schema that is used for storing the set of forecast series variables is compatible with that used by HPFENGINE procedure for its OUTFOR data set and is described in Table 5.17. Data flow through the TSMFor object is illustrated in Figure 5.6

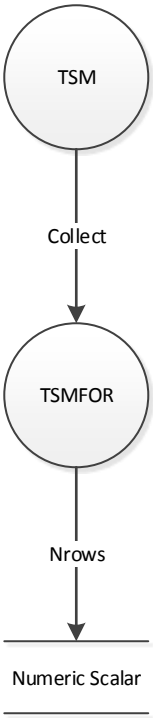
Table 5.17 Forecast Series Variables

Column	Type	Description
NAME	String	Name of the dependent variable
TIMEID	Numeric	Uniform time ID values for series
ACTUAL	Numeric	Accumulated values of dependent variable
PREDICT	Numeric	Forecasts of dependent variable

Table 5.17 *continued*

Column	Type	Description
ERROR	Numeric	Residuals
STD	Numeric	Prediction standard error
UPPER	Numeric	Upper confidence limit
LOWER	Numeric	Lower confidence limit

Figure 5.6 TSMFor Object Data flow



TSMFor Synopsis

The object declaration statement creates a new object, *obj*, of type **TSMFor**.

DECLARE OBJECT *obj (TSMFor)* **;**

Table 5.18 summarizes the methods of the TSMFor object:

Table 5.18 Methods of the TSMFor Object

TSMFor Method	Description
Collect	Collects forecasts estimates from TSM objects.
nrows	Returns the number of rows collected.

TSMFor Methods

This section describes the methods of a TSMFor object.

TSMFor.Collect Method

The collect method collects the forecast series from a TSM object, *ModelObj*. An optional *Region* argument can be specified to indicate the forecast region to be collected.

Usage: *rc* **=** *obj***.Collect** *(ModelObj* < *, Region* > *)* **;**

Parameters

[in] **ModelObj** Character string name of the TSM object to use as the source of time series model forecasts.

[in] **Region** Optional character string or numeric array to specify the time region to be collected. The default is ALL. Data types for Region are described in Table 5.19

Table 5.19 *Region* Argument Data Types

Type	Meaning
String	Collection region (ALL | FIT | HORIZON; the default is ALL)
Numeric[2]	Numeric[1]=Start time ID, Numeric[2]=End time ID (missing=default)

TSMFor Attributes

The TSMFor object contains a single attribute, which is describe next.

TSMFor.nrows Method

The nrows method returns the number of rows—an attribute of the TSMFor object—that have been collected.

Usage: *rc* **=** *obj***.nrows** *( )* **;**

TSMINEst Object Summary

The time series model input estimates (TSMINEst) repeater object imports parameter estimates from a CAS table for use in a TSM object. The TSMINEst table schema required for the parameter estimates is compatible with that used by the TSMPEst collector object. TSMINEst object must be used in conjunction with a TSMINSpec spec object and a TSM model object to replay a model with its saved parameters (for an example, see Example 5.3).

TSMINEst Synopsis

The object declaration statement creates a new object, *obj*, of type **TSMINEst**.

DECLARE OBJECT *obj (TSMINEst)* **;**

Table 5.20 summarizes the methods of the TSMINEst object.

Table 5.20 Methods of the TSMINEst Object

TSMINEst Method	Description
nrows	Returns number of rows in the TSMINEst object

TSMINEst Methods

There are no methods associated with this object.

TSMINEst Attributes

The TSMINEst object contains a single attribute, which is describe next.

TSMINEst.nrows Attribute

Returns the number of rows in the TSMINEst object, *obj*. A returned missing value indicates that the object has not been successfully configured.

Usage: *rc* **=** *obj***.nrows** *( )* **;**

TSMINSpec Object Summary

The time series model input specification (TSMINSpec) repeater object imports model specifications from a CAS table for use in a TSM object. The TSMINSpec table schema required for the model specification is compatible with that used by the TSMSpec collector object.

TSMINSpec Synopsis

The object declaration statement creates a new object, *obj*, of type **TSMINSpec**.

DECLARE OBJECT *obj* *(***TSMINSpec***)* **;**

Table 5.21 summarizes the methods of the TSMINSpec object.

Table 5.21 Methods of the TSMINSpec Object

TSMINSpec Method	Description
nrows	Number of rows in TSMINSpec object

TSMINSpec Methods

There are no methods associated with this object.

TSMINSpec Attributes

The TSMINSpec object contains a single attribute, which is describe next.

TSMINSpec.nrows Attribute

The nrows attribute returns the number of rows in the TSMINSpec object. A returned missing value indicates that the TSMINSpec object has not been successfully configured.

Usage: *rc* **=** *obj***.nrows** *( )* **;**

Examples: TSM Package

Throughout this section it is assumed that you have already started a CAS session and the data tables that are used in this section are in mycas, a CAS library that you have necessary permissions to work with. In all the examples of this section, the functionality of the TSM package is illustrated using the TSMODEL procedure. This section assumes that you are familiar with the general workings of the TSMODEL procedure; for more information, see Chapter 2, "The TSMODEL Procedure" (*SAS Visual Forecasting: Forecasting Procedures*).

Example 5.1: Fitting and Forecasting with ARIMA and ESM Models

The airline passenger data, given as Series G in Box and Jenkins (1976), have been used in time series analysis literature as an example of a nonstationary seasonal time series; for more information on ARIMA

modeling of Series G, see "Example 7.2 Seasonal Model for the Airline Series" in the ARIMA chapter of *SAS/ETS User's Guide*. This example shows how you can use the objects in the TSM package to fit the airline model, ARIMA(0,1,1)×(0,1,1)$_{12}$ NOINT, and the Winters exponential smoothing model to the airline series. In particular, it shows how you can do the following:

- Create ARIMA and ESM specifications by using the ARIMASPec and ESMSpec specification objects.
- Use these specification objects to initialize the TSM model objects.
- Use these TSM model objects to fit the airline model and Winters model to the airline series, and to forecast the series according to these models.
- Postprocess the forecast results to compute an ad hoc statistic.
- Output the computed results to CAS tables.

The broad outline of this program is as follows:

- The PROC TSMODEL statement specifies the input data set (mycas.air), a variety of output tables (mycas.airFor, mycas.airEst, and so on), and the forecast lead (12).
- The ID statement specifies date as the time index variable, and the INTERVAL= option indicates that the data are monthly.
- The VAR statement specifies the input data set variable, air, which contains the airline series.
- The OUTARRAYS and OUTSCALARS statements declare some output arrays and scalars that are used to store the analysis results, which are subsequently saved as CAS tables.
- The REQUIRE statement specifies the TSM package, which is needed for the analysis.
- The statements between the SUBMIT and ENDSUBMIT statements use the TSM package objects to perform the actual analysis in your CAS session.
- These statements are grouped in three sections:
  - The first section does the specification, fitting, and forecasting according to the airline model. The airSpec object contains the airline specification, and the airModel object is a TSM model object that is initialized by using airSpec. After the airModel is run, the parameter estimates are collected in airEst and the forecasts are collected in airFor. The model residuals are stored in the airErr array for later processing.
  - The second section does the specification, fitting, and forecasting according to the Winters exponential smoothing model. The esmSpec object contains the Winters specification and the esmModel object is a TSM model object that is initialized by using esmSpec. The esmModel is run, and the model residuals are stored in the esmErr array for later processing.
  - The third section computes an ad hoc statistic called nbetter, which counts the number of times the airline model residuals are smaller (in absolute size) than the Winters model. This section is included merely to illustrate how you can write your own custom postprocessing code to analyze the results that are produced by the TSM objects.

```
proc tsmodel data=mycas.air
   outobj=(airFor=mycas.airFor airEst=mycas.airEst)
   outscalar=mycas.nbetter
   outarray = mycas.out
   lead=12;
   id date interval=month;
   var air;
   outarrays esmErr airErr;   **store residuals of ESM and ARIMA models;
   outscalars nbetter nfor;
   require tsm;
   submit;
    **temporary work arrays used in ARIMA spec;
    array diff[2]/nosymbols;
    array ma[1]/nosymbols;

    *** Analysis based on Airline Model ***;
    declare object airModel(tsm);
    declare object airSpec(arimaspec);

    *** --setup the airline model spec:   --*;
    ** -- model: log(air) ~ (0,1,1)(0,1,1)12 noint --***;
    rc = airSpec.Open( );
    *** Specify differencing orders ***;
    diff[1] = 1;
    diff[2] = 12;
    rc = airSpec.SetDiff(diff,2);
    *** Specify MA orders: q = (1)(12)             ***;
    *** Use AddMAPoly twice  for the two factors   ***;
    ma[1] = 1;
    rc = airSpec.AddMAPoly(ma);
    ma[1] = 12;
    rc = airSpec.AddMAPoly(ma);
    *** Specify NOINT             ***;
    rc = airSpec.SetOption('noint',1);
    *** Specify log transform     ***;
    rc = airSpec.SetTransform('log');
    *** done setting up ARIMA model ***;
    rc = airSpec.Close( );

    *** setup and run the airModel TSM object ***;
    rc = airModel.Initialize(airSpec);
    rc = airModel.SetY(Air);
    rc = airModel.SetOption('lead',12);
    rc = airModel.Run( );

    *** output Airline Model forecasts and estimates ***;
    declare object airFor(tsmfor);
    declare object airEst(tsmpest);
    rc = airFor.Collect(airModel);
    rc = airEst.Collect(airModel);

    **put Airline Model residuals in airErr array;
    rc = airModel.getForecast('error',airErr);
```

```
      *** Analysis based on ESM Model ***;
      declare object esmModel(tsm);
      declare object esmSpec(esmspec);
      rc = esmspec.open( );
      rc = esmspec.SetOption('method', 'winters');
      rc = esmspec.close( );

      *** setup and run the TSM object ***;
      rc = esmModel.Initialize(esmspec);
      rc = esmModel.SetY(Air);
      rc = esmModel.SetOption('lead',12);
      rc = esmModel.Run( );
      **put ESM Model residuals in esmErr array;
      rc = esmModel.getForecast('error',esmErr);

     **--Compute an ad hoc statistic based on airErr and esmErr arrays;
      nbetter = 0;
      nfor = esmModel.nfor( );
      do t=1 to nfor;
         if airErr[t] ^= . & esmErr[t] ^= . then do;
            if abs(airErr[t]) < abs(esmErr[t])
               then nbetter = nbetter + 1;
         end;
      end;
   endsubmit;
  quit;
```

Output 5.1.1 shows the predictions, and Output 5.1.2 shows the parameter estimates for the airline model.

Output 5.1.1 Airline Model Predictions (Partial Output)

Airline Model Predictions

DATE	PREDICT	STD	UPPER	LOWER
JAN1961	450.4	16.9215	484.5	418.2
FEB1961	426.1	18.8590	464.2	390.3
MAR1961	480.1	24.0408	528.9	434.7
APR1961	492.8	27.2405	548.3	441.6
MAY1961	509.5	30.5863	572.0	452.1
JUN1961	584.2	37.6514	661.4	513.9
JUL1961	670.7	45.9957	765.3	585.1
AUG1961	668.2	48.4237	768.0	578.3
SEP1961	559.6	42.6271	647.7	480.7
OCT1961	498.3	39.7181	580.6	425.0
NOV1961	431.2	35.8240	505.5	365.2
DEC1961	478.9	41.3484	565.0	403.0

Output 5.1.2 Airline Model Parameter Estimates (Partial Output)

Airline Model Parameter Estimates

EST	_STDERR_	_TVALUE_	_PVALUE_
0.3773	0.0820	4.6033	9.828E-6
0.5724	0.0780	7.3361	2.17E-11

Output 5.1.3 shows the number of times the airline model residuals are smaller than the Winters model residuals.

Output 5.1.3 Number of Times the Airline Model Residuals Are Smaller Than the Winters Model Residuals

nbetter
71.0000

Example 5.2: Fitting a Transfer Function Model

This example uses the gas furnace data from Box and Jenkins (1976). The data, called Series J by Box and Jenkins, contain sequentially recorded measurements of two variables: x, the input gas rate, and y, the output CO_2. The data also include an index variable, time, which keeps track of the sequence number of each observation (essentially the row index). The TSMODEL procedure requires an ID variable that has a valid time interval associated with it to index the observations. In order to satisfy this requirement, time has been assigned second as the time interval (which is one of the simplest interval types for sequential indexing). As shown in "Example 7.3 Model for Series J Data from Box and Jenkins" in the ARIMA chapter of *SAS/ETS User's Guide*, a reasonable ARIMAX model for y turns out be $y = \text{TFinput(x)} + \text{AR(2)}$, where TFinput(x) is a transfer function term in x with a delay of 3, numerator polynomial of order 2, denominator polynomial of order 1; and AR(2) is an error term of autoregressive order 2. The following statements show you how to fit this model by using the objects in the TSM package:

```
proc tsmodel data=mycas.seriesj
   outobj=(jEst=mycas.jEst);
   id time interval=second;
   var x y;
   require tsm;
   submit;

    *** Transfer Function Modeling for seriesJ ***;
    declare object jModel(tsm);
    declare object jSpec(arimaspec);
    declare object jEst(tsmpest);

    array num[2]/nosymbols;
    array den[1]/nosymbols;
    array ar[2]/nosymbols;

    *** setup the Transfer Function Model spec:   ***;
    rc = jSpec.Open( );

    *** Specify AR orders: p = (1 2)               ***;
```

```
      ar[1] = 1;
      ar[2] = 2;
      rc = jSpec.AddARPoly(ar);

      rc = jSpec.AddTF('x', 3); *delay=3;
      num[1] = 1;
      num[2] = 2;
      rc = jSpec.AddTFNumPoly('x', num);
      den[1] = 1;
      rc = jSpec.AddTFDenPoly('x', den);
      *** done setting up ARIMA model ***;
      rc = jSpec.Close( );

      *** setup and run the TSM object ***;
      rc = jModel.Initialize(jSpec);
      rc = jModel.SetY(y);
      rc = jModel.AddX(x);
      rc = jModel.Run( );

      *** output Airline Model forecasts and estimates ***;
      rc = jEst.Collect(jModel);
   endsubmit;
  quit;
```

Output 5.2.1 shows the parameter estimates for the transfer function model.

Output 5.2.1 Parameter Estimates for the Transfer Function Model (Partial Output)

EST	_STDERR_	_TVALUE_	_PVALUE_
53.2630	0.1193	446.5	0
1.5329	0.0475	32.2472	6.25E-97
-0.6330	0.0501	-12.6434	2.27E-29
-0.5352	0.0748	-7.1534	7.21E-12
0.3760	0.1029	3.6553	0.000306
0.5189	0.1078	4.8124	2.425E-6
0.5484	0.0382	14.3499	1.72E-35

Example 5.3: Replaying a Previously Fitted Model

In some cases, it is useful to save the model specification and parameter estimates that are computed during an analysis for later use. For example, you can use the saved model specification and parameter estimates to produce model forecasts at a later stage (possibly with new measurements appended to the original data set). This example shows how you can do the following:

- Save the model specification and parameter estimates for later use by using the Collect method of the TSMSpec and TSMPest objects, respectively.
- Reuse the previously saved model specification and parameter estimates to configure a TSM object by using the Replay method.
- Produce the model forecasts by using this TSM object.

The following statements fit the airline model to the airline series (see Example 5.1 for more information about the airline series and the airline model). The model specification and parameter estimates are stored in CAS tables mycas.airOSpec and mycas.airEst, respectively.

```
proc tsmodel data=mycas.air
 outobj=(airEst=mycas.airEst airOSpec=mycas.airOSpec) ;
 id date interval=month;
 var air;
 require tsm;
 submit;
     *** Analysis based on Airline Model ***;
     declare object airModel(tsm);
     declare object airSpec(arimaspec);
     declare object airEst(tsmpest);
     declare object airOSpec(tsmspec);

     array diff[2]/nosymbols;
     array ma[1]/nosymbols;

     *** setup the airline model spec:   ***;
     ** model: log(air) ~ (0,1,1)(0,1,1)12 noint ***;
     rc = airSpec.Open();
     *** Specify differencing orders ***;
     diff[1] = 1;
     diff[2] = 12;
     rc = airSpec.SetDiff(diff,2);
     *** Specify MA orders: q = (1)(12)             ***;
     *** Use AddMAPoly twice  for the two factors   ***;
     ma[1] = 1;
     rc = airSpec.AddMAPoly(ma);
     ma[1] = 12;
     rc = airSpec.AddMAPoly(ma);
     *** Specify NOINT             ***;
     rc = airSpec.SetOption('noint',1);
     *** Specify log transform     ***;
     rc = airSpec.SetTransform('log');
     *** done setting up ARIMA model ***;
     rc = airSpec.Close();

     *** setup and run the TSM object ***;
     rc = airModel.Initialize(airSpec);
     rc = airModel.SetY(Air);
     rc = airModel.SetOption('lead',12);
     rc = airModel.Run();

     *** output Airline Model spec and estimates ***;
     rc = airEst.Collect(airModel);
     rc = airOSpec.Collect(airModel);
 endsubmit;
quit;
```

Output 5.3.1 shows the parameter estimates that are saved in mycas.airEst.

Output 5.3.1 Parameter Estimates for the Airline Model (Partial Output)

Airline Model Parameter Estimates

EST	_STDERR_	_TVALUE_	_PVALUE_
0.3773	0.0820	4.6033	9.828E-6
0.5724	0.0780	7.3361	2.17E-11

The following statements show you how to forecast the airline series by using the previously saved model specification (mycas.airOSpec) and parameter estimates (mycas.airEst).

```
proc tsmodel data=mycas.air
outobj=(airFor=mycas.airFor)
inobj=(airEst=mycas.airEst airSpec=mycas.airOSpec) ;
id date interval=month;
var air;
require tsm;
submit;
    *** Analysis based on Airline Model ***;
    declare object airModel(tsm);
    declare object airSpec(tsminspec);
    declare object airEst(tsminest);
    declare object airFor(tsmfor);

    *** setup and run the TSM object ***;
    rc = airModel.Initialize();
    rc = airModel.SetY(Air);
    rc = airModel.SetOption('lead',12);
    rc = airModel.Replay(airSpec,airEst);
    rc = airModel.Run();

    *** output Airline Model forecasts ***;
    rc = airFor.Collect(airModel);
endsubmit;
quit;
```

Output 5.3.2 shows the forecasts that are produced according to the fitted model.

Output 5.3.2 Replayed Forecasts (Partial Output)

Airline Model Predictions

DATE	PREDICT	STD	UPPER	LOWER
JAN1961	450.4	16.9215	484.5	418.2
FEB1961	426.1	18.8590	464.2	390.3
MAR1961	480.1	24.0408	528.9	434.7
APR1961	492.8	27.2405	548.3	441.6
MAY1961	509.5	30.5863	572.0	452.1
JUN1961	584.2	37.6514	661.4	513.9
JUL1961	670.7	45.9957	765.3	585.1
AUG1961	668.2	48.4237	768.0	578.3
SEP1961	559.6	42.6271	647.7	480.7
OCT1961	498.3	39.7181	580.6	425.0
NOV1961	431.2	35.8240	505.5	365.2
DEC1961	478.9	41.3484	565.0	403.0

References

Box, G. E. P., and Jenkins, G. M. (1976). *Time Series Analysis: Forecasting and Control*. Rev. ed. San Francisco: Holden-Day.

Chapter 6
Utility Package for the TSMODEL Procedure

Contents

Overview

This document describes the various utility object classes that are contained in the UTL package. The purpose of the UTL package is to provide a means for performing basic statistical computations on pairs of actual and predicted time series. The following types of computations are currently supported by the UTL package:

1. Computation of prediction standard errors and confidence limits for specified actual and predicted time series.
2. Computation and storing of model forecast fit statistics into CAS tables for specified actual and predicted time series.
3. Storing of ad hoc numeric variables that are defined in a user program into CAS tables.

The UTL package is object-oriented. To use the UTL package, you must declare instances of the object classes that are contained in the package. Declaring an object instance is the object-oriented equivalent of declaring a program variable. As with simple program variables, the declaration assigns the instance a name of your choosing and a type, which is defined by the object's class. Unlike simple program variables, the object instance requires a different syntax for interacting with it and offers different functions (methods) that are contextual to the object. The object can offer very sophisticated capabilities with a simple-to-use interface.

UTL Package Summary

Table 6.1 summarizes the object classes that are contained in the UTL package.

Table 6.1 Classes in the Utility Package

UTL Function	Description
CLIMITS	Compute prediction standard errors and confidence limits for specified actual and predicted time series.
OUTNVP	Ad hoc name,value pair collector object for storing numeric scalar or array variables that are found in a user program into a CAS table.
UTLSTAT	Collector object for computing forecast fit statistics for specified actual and predicted time series and storing those statistics in a CAS table.

Using the UTL Package

The objects in the UTL package are subdivided into two different categories:

1. Stateful computational objects (the CLIMITS object)
2. Collector objects (the OUTNVP and UTLSTAT objects)

Collector objects provide a mechanism to create a snapshot of results (either from stateful objects or from plain program variables) and store those results into CAS tables. Each collector object defines a CAS table schema that is determined by the collector object's design. The collector objects in the UTL package (OUTNVP and UTLSTAT) follow a common method pattern. The basic execution follows this sequence of operations:

1. **Declare**: Create the collector object by using the object declaration statement.
2. **Collect**: Use the Collect method to store results into a CAS table. The input arguments of the Collect method are specific to the collector object. For example, the UTLSTAT collector object's Collect method requires an actual and predicted time series as arguments. It then uses the specified series to compute forecast fit statistics and stores the results in a CAS table. In contrast, the OUTNVP

collector object's Collect method takes in an ad hoc numerical scalar or array variable from the user program and stores it into a CAS table. Rows that are collected are automatically appended to the collector's associated CAS table at the end of each BY group, and the collector object's saved row set is automatically reset. The Nrows attribute returns the current row count in the collector. A missing value is returned if nothing has been collected. The data, now stored in CAS tables, can then be used to produce reports or be used in further computations.

Common Argument Types

Table 6.2 defines the common argument types that are used in this chapter.

Table 6.2 Common Argument Types

SAS Data Type	Declaration Syntax
String	LENGTH *x* **$***n***;**
Numeric	*x* or LENGTH *x 8***;**
Numeric array	ARRAY *x***[***n***]**/NOSYMBOLS**;**
Status	*x* or LENGTH *x 8***;**

Status Code Convention

Table 6.3 shows the return code (rc) values that are used by all objects in this chapter.

Table 6.3 Status Codes

rc Value	Meaning
< 0	An unrecoverable error occurred. No result was produced.
= 0	Unconditional success. Requested action completed and normal result produced.
> 0	Conditional success or warning. A result was produced subject to conditions.

Upon returning a negative status code, most methods in the UTL package objects also write a message to the output log that explains the causes of the related failure. These messages provide extremely useful information during the process of debugging a user program. In the TSMODEL procedure, the output log is stored in the CAS table that is specified in the OUTLOG= option in the PROC TSMODEL statement. For more information about how to enable and configure logging and about how to access the output log after an invocation of the TSMODEL procedure, see Chapter 2, "The TSMODEL Procedure" (*SAS Visual Forecasting: Forecasting Procedures*). Subsequent sections of this document describe the UTL package object classes and their use.

CLIMITS Object Summary

The CLIMITS object provides a mechanism for computing both the prediction standard errors and confidence limits of an *external model* (that is, a user-defined model) forecast, which is described by a pair of actual and predicted time series. The first stage of the computational process involves validating both input series. This validation is accomplished by ascertaining that the actual and predicted series have nonmissing observation values under at least one matching index. In addition, the predicted series is checked for the presence of extreme values. Next, the prediction standard errors are computed from the prediction errors (that is, the model residuals). Finally, the confidence limits are computed from the prediction standard errors. You can optionally supply the value of the confidence level that is used to compute the confidence limits. Note that the CLIMITS object retains all computed results in its internal memory. Individual forecast series can be queried via the GetForecast method, which is a method in the CLIMITS object.

CLIMITS Synopsis

The object declaration statement creates a new object, *obj*, of type CLIMITS:

DECLARE OBJECT *obj* (**CLIMITS**) **;**

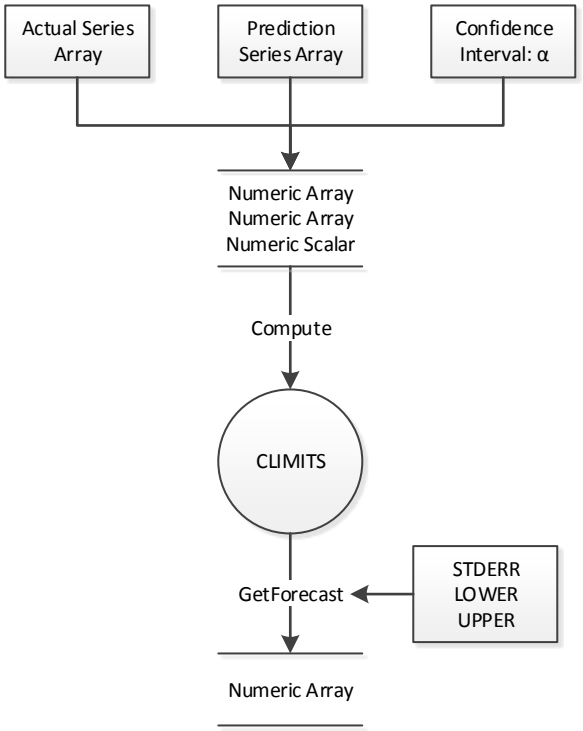
Table 6.4 summarizes the methods that are associated with the CLIMITS object.

Table 6.4 Methods of the CLIMITS Object

CLIMIT Method	Description
Compute	Compute the prediction standard errors and confidence limits for specified actual and predicted time series.
GetForecast	Retrieve a computed forecast series by name.

Figure 6.1 outlines the programmatic data flow through the CLIMITS object.

Figure 6.1 CLIMITS Object Data Flow



CLIMITS Methods

This section describes the methods of a CLIMITS object.

CLIMITS.Compute Method

The Compute method computes the prediction standard errors and confidence limits for specified actual and predicted time series.

Usage: *rc* **=** *obj*.**Compute** *(Actual, Predicted, < Alpha >)* **;**

Both input series are validated by ascertaining the presence of nonmissing observation values under at least one matching index. Also, the predicted series is checked for the presence of extreme values. The computed forecast series are stored in the object's internal memory and can be individually queried via the GetForecast method into a numeric array defined in the user program. A negative return code indicates that the validation of an input series failed (for example, the predicted series has extreme values or all missing values), you specified an out-of-range *Alpha* argument value, or a computational failure occurred (for example, out-of-memory error).

Parameters

[in] *Actual* Numeric array that corresponds to the actual time series.

[in] *Predicted* Numeric array that corresponds to the predicted time series.

[in] *Alpha* Optional numeric literal or variable that specifies the confidence level used to compute the lower and upper confidence limits. The default value is 0.05.

CLIMITS.GetForecast Method

The GetForecast method places the specified forecast series, *Which*, from the CLIMITS object into the specified numeric array, *Result*.

Usage: *rc* = *obj*.**GetForecast** *(Which, Result)* **;**

Forecast series have the same length as the predicted series that is supplied to the Compute method via its *Predicted* argument. The GetForecast method returns a negative status code if the Compute method returned a non zero value or if it was not yet executed (that is, no results exist to be queried).

Parameters

[in] *Which* Character literal or string whose value specifies the forecast series to return. Table 6.5 shows the series types that are supported.

Table 6.5 'Which' Parameters for the CLIMITS.GetForecast Method

Which	Meaning
STDERR	Forecast standard error series
UPPER	Upper confidence limit series
LOWER	Lower confidence limit series

[out] *Result* Numeric array to receive the forecast series. If the array length is longer than the requested series, it is padded with missing values.

OUTNVP Object Summary

The OUTNVP collector object is a powerful tool that collects any ad hoc numeric variables that are defined in the user program into CAS tables. The OUTNVP collector object accepts any of the following numeric types: scalar literal, scalar variable, and array variable. The CAS table schema for the OUTNVP object contains the columns that are shown in Table 6.6.

Table 6.6 CAS Table Schema for the OUTNVP Collector Object

Column	Type	Description
NAME	String	Name of the variable
CALL	Numeric	Call count within the BY group
UTAG	Numeric	User-defined numeric tag
VIX	Numeric	Value index (1-based) for the row
VALUE	Numeric	Actual value for variable's row

OUTNVP Synopsis

The object declaration statement creates a new collector object, *obj*, of type OUTNVP:

DECLARE OBJECT *obj* (**OUTNVP**) **;**

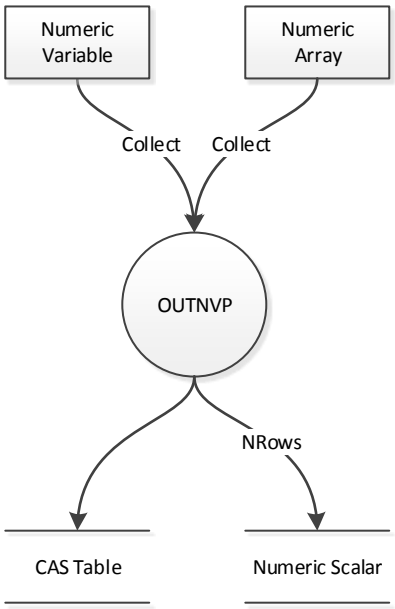
Table 6.7 summarizes the methods and attributes that are associated with the OUTNVP object.

Table 6.7 Methods of the OUTNVP Object

OUTNVP Method	Description
Collect	Collect value for numeric data type (scalar literal or variable or array variable).
nrows	Get the OUTNVP instance row count.

Figure 6.2 outlines the programmatic data flow through the OUTNVP object.

Figure 6.2 OUTNVP Object Data Flow



OUTNVP Methods

This section describes the methods of an OUTNVP collector object.

OUTNVP.Collect Method

The Collect method stores a numeric type, either scalar literal or variable or array variable in the OUTNVP table. When the *Variable* parameter is a numeric scalar literal or variable, this method collects a single row into the OUTNVP table. When the *Variable* parameter is a numeric array variable, this method collects a sequence of rows for the span of indices in the array. If the optional parameter *Utag* is specified, its value is included in the _UTAG_ column of each collected OUTNVP row. The name of the collected variable is also included in the _NAME_ column of each collected OUTNVP row. Similarly, the value of a counter that counts the number of calls to this method that are made within a BY group is also included in column _CALL_ of each OUTNVP row. A negative return value indicates that an error occurred while storing results into a CAS table.

Usage: *rc* **=** *obj*.**Collect** *(Variable, < Utag >)* **;**

Parameters

[in] *Variable* Numeric scalar literal or variable or array variable to be collected into the OUTNVP table.

[in] *Utag* Optional numeric scalar literal or variable whose value is to be included in the _UTAG_ column of the OUTNVP table. The default value is a missing value.

OUTNVP.nrows Attribute

The Nrows attribute returns the number of rows that have been collected and stored in the CAS table.

Usage: *rc* **=** *obj***.nrows** *()* **;**

Parameters

There are no parameters associated with this method.

UTLSTAT Object Summary

The UTLSTAT collector object is used to conveniently compute a number of forecast fit statistics for an ad hoc pair of user-specified actual and predicted time series. The computed forecast fit statistics are automatically stored in a CAS table. For each ad hoc pair of actual and predicted time series that is input into a UTLSTAT collector object, a single row of forecast fit statistics is added to the underlying CAS table. The CAS table schema that is used by the UTLSTAT object is compatible with the schema used by the HPFENGINE procedure for its OUTSTAT data set. The table schema is shown in Table 6.8. For more information about the HPFENGINE procedure, see *SAS Forecast Server Procedures: User's Guide*.

Table 6.8 CAS Table Scheme for the UTLSTAT Collector Object

Column	Type	Description
NAME	String	Variable name of actual series
MODEL	String	Variable name of predicted series
DFE	Numeric	Degrees of freedom error
N	Numeric	Number of observations
NOBS	Numeric	Number of observations used
NMISSA	Numeric	Number of missing actuals
NMISSP	Numeric	Number of missing predicted values
NPARMS	Numeric	Number of model parameters
TSS	Numeric	Total sum of squares
SST	Numeric	Corrected total sum of squares

Table 6.8 *continued*

Column	Type	Description
SSE	Numeric	Sum of square error
MSE	Numeric	Mean square error
RMSE	Numeric	Root mean square error
UMSE	Numeric	Unbiased mean square error
URMSE	Numeric	Unbiased root mean square error
MAPE	Numeric	Mean absolute percentage of error
MAE	Numeric	Mean absolute error
RSQUARE	Numeric	R-square
ADJRSQ	Numeric	Adjusted R-square
AADJRSQ	Numeric	Amemiya's adjusted R-square
RWRSQ	Numeric	Random walk R-square
AIC	Numeric	Akaike's information criterion
AICC	Numeric	Finite sample corrected Akaike's information criterion
SBC	Numeric	Schwarz Bayesian information criterion
APC	Numeric	Amemiya's prediction criterion
MAXERR	Numeric	Maximum error
MINERR	Numeric	Minimum error
MAXPE	Numeric	Maximum percentage of error
MINPE	Numeric	Minimum percentage of error
ME	Numeric	Mean error
MPE	Numeric	Mean percentage of error
MDAPE	Numeric	Median absolute percentage of error
GMAPE	Numeric	Geometric mean absolute percentage of error
MINPPE	Numeric	Minimum predicted percentage of error
MAXPPE	Numeric	Maximum predicted percentage of error
MPPE	Numeric	Mean predicted percentage of error
MAPPE	Numeric	Mean absolute predicted percentage of error
MDAPPE	Numeric	Median absolute predicted percentage of error
GMAPPE	Numeric	Geometric mean absolute predicted percentage of error

Table 6.8 *continued*

Column	Type	Description
MINSPE	Numeric	Minimum symmetric percentage of error
MAXSPE	Numeric	Maximum symmetric percentage of error
MSPE	Numeric	Mean symmetric percentage of error
SMAPE	Numeric	Mean absolute symmetric percentage of error
MDASPE	Numeric	Median absolute symmetric percentage of error
GMASPE	Numeric	Geometric mean absolute symmetric percentage of error
MINRE	Numeric	Minimum relative error
MAXRE	Numeric	Maximum relative error
MRE	Numeric	Mean relative error
MRAE	Numeric	Mean relative absolute error
MDRAE	Numeric	Median relative absolute error
GMRAE	Numeric	Geometric mean relative absolute error
MASE	Numeric	Mean absolute scaled error
MINAPES	Numeric	Minimum absolute error percentage of standard deviation
MAXAPES	Numeric	Maximum absolute error percentage of standard deviation
MAPES	Numeric	Mean absolute error percentage of standard deviation
MDAPES	Numeric	Median absolute error percentage of standard deviation
GMAPES	Numeric	Geometric mean absolute error percentage of standard deviation

UTLSTAT Synopsis

The object declaration statement creates a new collector object, *obj*, of type UTLSTAT:

DECLARE OBJECT *obj* (**UTLSTAT**) **;**

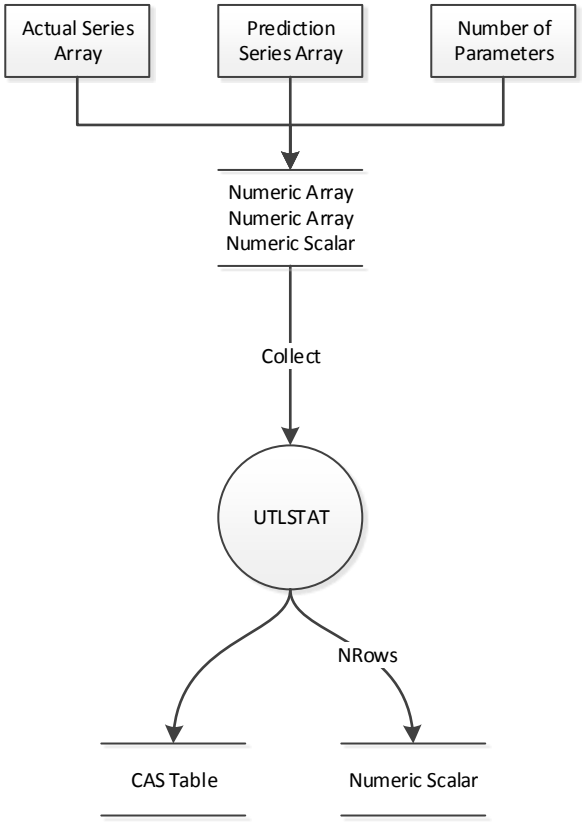
Table 6.9 summarizes the methods of the UTLSTAT object:

Table 6.9 Methods of the UTLSTAT Object

UTLSTAT Method	Description
Collect	Compute and collect forecast fit statistics for a specified ad hoc pair of actual and predicted time series.
nrows	Get the UTLSTAT instance row count.

Figure 6.3 outlines the programmatic data flow through the UTLSTAT object.

Figure 6.3 UTLSTAT Object Data Flow



UTLSTAT Methods

This section describes the methods of an UTLSTAT collector object.

UTLSTAT.Collect Method

The Collect method computes and collects forecast fit statistics for an ad hoc pair of specified actual time series and predicted time series. Each call collects a single row into the UTLSTAT CAS table, which contains all the forecast fit statistics that are listed in Table 6.8. A negative return value indicates that an error occurred either during the computation of the forecast fit statistics or while storing results into a CAS table. The values of the forecast fit statistics computed by this method are sensitive to the value of optional parameter *Nparms*, which specifies the number of parameters that were used by the model that generated the predicted time series.

Usage: *rc* **=** *obj*.**Collect** *(Actual, Predicted, < Nparms >)* **;**

Parameters

[in] *Actual* Numeric array that specifies the actual series.

[in] *Predicted* Numeric array that specifies the predicted series.

[in] *Nparms* Optional numeric scalar literal or variable that specifies the number of parameters used by the model that generated the predicted series. The default value is 0.

UTLSTAT.nrows Attribute

The Nrows attribute returns the number of rows that have been collected and stored in the CAS table.

Usage: *rc* **=** *obj*.**nrows** *()* **;**

Parameters

There are no parameters associated with this method.

Examples: UTL Package for the TSMODEL Procedure

Example 6.1: Collecting Forecast Fit Statistics and Ad Hoc Numeric Variables into CAS Tables

This example demonstrates the capabilities of the UTLSTAT and OUTNVP collector objects from the UTL package. The UTLSTAT collector object is used to compute and collect forecast fit statistics for a specified pair of actual and predicted time series. In contrast, the OUTNVP collector object is used to store ad hoc numeric variables that are found in the user-defined program into CAS tables. The example starts by using a DATA step to load a sample time series data set called Sashelp.Air into a CAS table. The TSMODEL procedure is then invoked and the Time Series Model (TSM) object (available in the TSM package) is used to generate a model for the Air series in the Sashelp.Air data set. Next, both the actual Air series and its predicted counterpart (generated by the TSM object) are input into the UTLSTAT object to compute and collect numerous forecast fit statistics (see Table 6.8) into a CAS table. Because this example processes only

a single time series (the Air series) and a single BY group, a single row of output is stored in the UTLSTAT table. The example then uses the OUTNVP collector object to store into a CAS table various forecast series that are retrieved from the TSM object. Each forecast series is first queried into a numeric array via the GetForecast method in the TSM object. Each array is then input directly, one by one, into the OUTNVP collector object. Finally, some results are retrieved from the resulting UTLSTAT and OUTNVP CAS tables, sorted, and printed for further inspection.

The following DATA step loads the Sashelp.Air data set onto the CAS server. This DATA step assumes that your CAS engine libref is named mycas, but you can substitute any appropriately defined CAS engine libref.

```
data mycas.air (replace=yes);
   set Sashelp.Air;
run;
```

The following statements use the TSMODEL procedure to perform time series modeling on a single BY group. Because no ACCUMULATE= option is specified in the ID or VAR statements, its default value of TOTAL is used, which accumulates observations within a time period as a total sum of the nonmissing values.

```
proc tsmodel data=mycas.air
    outarray = mycas.outarray (replace=yes)
    outscalar = mycas.outscalar (replace=yes)
    outobj=(
        utlstatobj = mycas.utlstat (replace = YES)
        outnvpmodelobj = mycas.outnvpmodel (replace = YES)
        )
    outlog = mycas.outlog (replace=yes)
    lead=12;
id date interval=month start='01jan1949'd end='01dec1960'd;
outarray predict error stderr lcl ucl;
outscalar rc1 rc2 rc3 rc4 rc5 rc6 rc7 rc8;
var air;
require tsm utl;
submit;
    /* Declare the "Time Series Model" (TSM) object and perform fit */
    declare object esm(tsm);
    rc1 = esm.Initialize();
    if rc1 < 0 then do; stop; end;
    rc1 = esm.SetY(air);
    if rc1 < 0 then do; stop; end;
    rc1 = esm.Run();
    if rc1 < 0 then do; stop; end;

    /* Retrieve forecast series computed internally by the TSM object */
    rc2 = esm.GetForecast('predict',predict); /*Predicted series*/
    if rc2 < 0 then do; stop; end;
    rc2 = esm.GetForecast('error',error);     /*Forecast error series*/
    if rc2 < 0 then do; stop; end;
    rc2 = esm.GetForecast('stderr',stderr);   /*Prediction std. errors series*/
    if rc2 < 0 then do; stop; end;
    rc2 = esm.GetForecast('lower',lcl);       /*Lower conf. limits series*/
    if rc2 < 0 then do; stop; end;
    rc2 = esm.GetForecast('upper',ucl);       /*Upper conf. limits series*/
    if rc2 < 0 then do; stop; end;
```

```
    /* Collect forecast series computed by the TSM object into a CAS table */
    declare object outnvpmodelobj(outnvp);
    rc3 = outnvpmodelobj.Collect(air,_SERIES_);
    if rc3 < 0 then do; stop; end;
    rc3 = outnvpmodelobj.Collect(predict,_SERIES_);
    if rc3 < 0 then do; stop; end;
    rc3 = outnvpmodelobj.Collect(error,_SERIES_);
    if rc3 < 0 then do; stop; end;
    rc3 = outnvpmodelobj.Collect(stderr,_SERIES_);
    if rc3 < 0 then do; stop; end;
    rc3 = outnvpmodelobj.Collect(lcl,_SERIES_);
    if rc3 < 0 then do; stop; end;
    rc3 = outnvpmodelobj.Collect(ucl,_SERIES_);
    if rc3 < 0 then do; stop; end;

    /* Compute and collect a vast number of forecast fit statistics */
    declare object utlstatobj(utlstat);
    rc4 = utlstatobj.Collect(air, predict);
    if rc4 < 0 then do; stop; end;
endsubmit;
run;
```

You can use the PRINT procedure to display a small subset of the 55 different forecast fit statistics that are collected by the UTLSTAT object. The PRINT procedure can access CAS tables directly; thus, there is no need to retrieve the UTLSTAT table back from CAS and into a local data set prior to display.

```
/* Print a few forecast fit statistics for the single BY group */
proc print data=mycas.utlstat;
    var _NAME_ _MODEL_ NOBS RMSE MAPE MAE RSQUARE AIC;
run;
```

Output 6.1.1 shows that a single row of data was collected. This row corresponds to the forecast fit statistics that were collected for a single forecast (that is, one pair of actual and predicted series) within the single BY group that was processed by the TSMODEL procedure call.

Output 6.1.1 Sample of the Forecast Fit Statistics Computed and Collected by the UTLSTAT Object

Obs	_NAME_	_MODEL_	NOBS	RMSE	MAPE	MAE	RSQUARE	AIC
1	AIR	predict	144	10.579085435	3.0845016398	8.0064787209	0.9921692375	679.35714621

You can use the PRINT procedure again to display a small subset of observations from the following six different series that were collected by the OUTNVP object into the mycas.outnvpmodel CAS table:

- The actual series (that is, the Air series).
- The predicted series that was generated by the TSM object.
- The forecast error series that was generated by the TSM object.
- The prediction standard errors series that was generated by the TSM object.
- The lower confidence limits series that was generated by the TSM object.
- The upper confidence limits series that was generated by the TSM object.

You can print in sequence the values of the first three observations in each of these six series, for a total of 18 rows. To accomplish this, you must sort the mycas.outnvpmodel CAS table in a manner that sequentially aligns all rows that correspond to each unique observation index in all collected series (that is, all rows that correspond to the first observation in all six series, followed by all rows that correspond to the second observation in all six series, and so on). You can use the SORT procedure to simultaneously sort a CAS table and retrieve the results into a local data set as follows:

```
/* Sort OUTNVP table by "row index" and "BY group Collect() call count"   */
/* (that is, _VIX_ and _CALL_ columns). Transfer the sorted table rows    */
/* back from CAS and into a local data set.                               */
proc sort data=mycas.outnvpmodel out=outnvpmodel;
    by _VIX_ _CALL_;
run;

/* Print the values of the first 18 rows, which correspond to the values  */
/* of the first 3 observations in the six collected series. These 18 rows */
/* correspond to the condition "1 <= _VIX_ <= 3" in the CAS table called  */
/* "MYCAS.OUTNVPMODEL".                                                   */
proc print data=outnvpmodel(obs=18);
run;
```

Output 6.1.2 Sample of the Six Ad Hoc Series Collected by the OUTNVP Object

Obs	_VAR_	_CALL_	_UTAG_	_VIX_	_VALUE_
1	AIR	1	0	1	112
2	predict	2	0	1	111.44700541
3	error	3	0	1	0.5529945856
4	stderr	4	0	1	10.691036547
5	lcl	5	0	1	90.492958825
6	ucl	6	0	1	132.401052
7	AIR	1	0	2	118
8	predict	2	0	2	119.94581467
9	error	3	0	2	-1.945814668
10	stderr	4	0	2	10.691036547
11	lcl	5	0	2	98.991768079
12	ucl	6	0	2	140.89986126
13	AIR	1	0	3	132
14	predict	2	0	3	135.17351431
15	error	3	0	3	-3.173514311
16	stderr	4	0	3	10.691036547
17	lcl	5	0	3	114.21946772
18	ucl	6	0	3	156.1275609

The sequence that is displayed in Output 6.1.2 was obtained by using the SORT procedure to sort the data in the OUTNVP table in increasing order of the columns _VIX_ (series row index) and _CALL_ (that is, the OUTNVP object's Collect method call count within BY group). For example, rows 1–6 contain the values of the first observation in each of the six collected series, which correspond to the rows in the mycas.outnvpmodel CAS table where column _VIX_ = 1: row 1 is the value of the first observation in the Air series (that is, column _VAR_ = `'AIR'`) and rows 2–6 are the values of the first observations in the Predict, Error, StdErr, LCL, and UCL forecast series that were retrieved from the TSM object via its GetForecast method. The same applies for the second observation in each of the six collected series as described by rows

7–12 (that is, rows where column _VIX_ = 2) and for the third observation in each of the six collected series as described by rows 13–18 (rows where column _VIX_ = 3).

Example 6.2: Computing Prediction Standard Errors and Confidence Limits for an Ad Hoc External Forecast

This example uses the TSMODEL procedure to compute the prediction standard errors and confidence limits of an ad hoc forecast that includes an actual and predicted time series. The example starts by using a DATA step to create a synthetic data set called ExternalModel. The synthetic data set contains three time series that make up an ad hoc *external model* (that is, a user-defined model) forecast: an actual series called Air, a simulated forecast error series called Error, and a simulated predicted series called Predict. This synthetic, ad hoc external forecast lacks the prediction standard errors and confidence limits, which will be computed by the CLIMITS object. Notice from the DATA step code that the actual time series is simply a copy of the Air series taken from the Sashelp.Air data set. The predicted time series is generated by simply adding a small amount of noise to the actual Air series. The added noise corresponds to random samples taken of the uniform distribution (which ranges from 0.0 to 1.0) multiplied by a factor of 10. Thus, the added noise samples range from 0.0 to 10.0 and have an expected value of 5.0. This expected value is important because it corresponds to the average forecast error of the simulated predicted series, a value that over many samples should approximate the prediction standard errors that will be computed by the CLIMITS object for this synthetic, ad hoc external forecast. Next, the synthetic data set is uploaded to a CAS table and the TSMODEL procedure is invoked. The actual and predicted time series are input to the CLIMITS object's Compute method to compute the prediction standard errors and confidence limits of the ad hoc external forecast. The CLIMITS object's GetForecast method is then used to retrieve the resulting three forecast series into numeric arrays that are defined in the user program. Finally, the OUTNVP collector object collects a total of six series into a CAS table: the actual Air series, the simulated predicted and forecast error series, and the three forecast series that were computed by the CLIMITS object. This was similarly done in Example 6.1 to store into a CAS table the actual series plus the five forecast series that were retrieved from the TSM object via its own GetForecast method. Finally, some results are retrieved from CAS tables, sorted, and printed for further inspection:

The following DATA step creates a synthetic data set that contains actual and simulated predicted time series:

```
data ExternalModel (replace=yes);
    set Sashelp.Air;                  /* The actual series: Sashelp.Air  */
    error = floor(10*ranuni(246));    /* Simulated forecast error series */
    predict = air + error;            /* Simulated predicted series      */
run;
```

The following DATA step loads the ExternalModel data set onto the CAS server. This DATA step assumes that your CAS engine libref is named mycas, but you can substitute any appropriately defined CAS engine libref.

```
data mycas.ExternalModel;
    set ExternalModel;
run;
```

The following statements use the TSMODEL procedure to compute the prediction standard errors and confidence limits of the ad hoc external forecast that resides in the synthetic data set:

```
proc tsmodel data = mycas.externalmodel
    outarray = mycas.outarray (replace=yes)
    outscalar = mycas.outscalar (replace=yes)
    outlog = mycas.outlog (replace=yes)
    outobj=( outnvpmodelobj = mycas.outnvpmodel (replace = YES) );
id date interval=month start='01jan1949'd end='01dec1960'd;
var air predict error;
outarrays stderr lcl ucl;
outscalar rc1 rc2 rc3;
require utl;
submit;
    /* Compute the prediction standard errors and confidence limits */
    declare object clim(CLIMITS);
    rc1 = clim.Compute(air,predict,0.05); /* Confidence level: 0.05 */
    if rc1 < 0 then do; stop; end;

    /* Retrieve the forecast series stored internally in the CLIMITS object   */
    rc2 = clim.GetForecast('stderr',stderr); /* Prediction sdt. errors series */
    if rc2 < 0 then do; stop; end;
    rc2 = clim.GetForecast('lower',lcl);     /* Lower conf. limits series     */
    if rc2 < 0 then do; stop; end;
    rc2 = clim.GetForecast('upper',ucl);     /* Upper conf. limits series     */
    if rc2 < 0 then do; stop; end;

    /* Collect the actual, predicted, and forecast error series, in addition */
    /* to the forecast series computed by the CLIMITS object into a CAS table*/
    declare object outnvpmodelobj(outnvp);
    rc3 = outnvpmodelobj.Collect(air,_SERIES_);
    if rc3 < 0 then do; stop; end;
    rc3 = outnvpmodelobj.Collect(predict,_SERIES_);
    if rc3 < 0 then do; stop; end;
    rc3 = outnvpmodelobj.Collect(error,_SERIES_);
    if rc3 < 0 then do; stop; end;
    rc3 = outnvpmodelobj.Collect(stderr,_SERIES_);
    if rc3 < 0 then do; stop; end;
    rc3 = outnvpmodelobj.Collect(lcl,_SERIES_);
    if rc3 < 0 then do; stop; end;
    rc3 = outnvpmodelobj.Collect(ucl,_SERIES_);
    if rc3 < 0 then do; stop; end;
endsubmit;
run;
```

Following what was done in Example 6.1, you can use the PRINT procedure to display a small subset of observations from the following six different series that were collected by the OUTNVP object into the mycas.outnvpmodel CAS table:

- The actual series (Air series) of the ad hoc external forecast.
- The simulated predicted series of the ad hoc external forecast.
- The simulated forecast error series of the ad hoc external forecast.
- The prediction standard errors series that were computed by the CLIMITS object for the ad hoc external forecast.

- The lower confidence limits series that were computed by the CLIMITS object for the ad hoc external forecast.
- The upper confidence limits series that were computed by the CLIMITS object for the ad hoc external forecast.

You can print in sequence the values of the first three observations in each of these six series, for a total of 18 rows. To accomplish this, you must sort the mycas.outnvpmodel CAS table in a manner that sequentially aligns all rows that correspond to each unique observation index in all collected series (all rows that correspond to the first observation in all six series, followed by all rows that correspond to the second observation in all six series, and so on). You can use the SORT procedure to simultaneously sort a CAS table and retrieve the results into a local data set as follows:

```
/* Sort OUTNVP table by "row index" and "BY group Collect() call count"   */
/* (that is, _VIX_ and _CALL_ columns). Transfer the sorted table rows    */
/* back from CAS and into a local data set.                               */
proc sort data=mycas.outnvpmodel out=outnvpmodel;
    by _VIX_ _CALL_;
run;

/* Print the value of the first 18 rows, which corresponds to the values  */
/* of the first 3 observations in the six collected series. These 18 rows */
/* correspond to the condition "1 <= _VIX_ <= 3" in the CAS table called  */
/* "MYCAS.OUTNVPMODEL".                                                   */
proc print data=outnvpmodel(obs=18);
run;
```

Output 6.2.1 Sample of the Six Ad Hoc Series Collected by the OUTNVP Object

Obs	_VAR_	_CALL_	_UTAG_	_VIX_	_VALUE_
1	AIR	1	0	1	112
2	predict	2	0	1	117
3	error	3	0	1	5
4	stderr	4	0	1	5.0408057116
5	lcl	5	0	1	107.12020235
6	ucl	6	0	1	126.87979765
7	AIR	1	0	2	118
8	predict	2	0	2	124
9	error	3	0	2	6
10	stderr	4	0	2	5.0408057116
11	lcl	5	0	2	114.12020235
12	ucl	6	0	2	133.87979765
13	AIR	1	0	3	132
14	predict	2	0	3	135
15	error	3	0	3	3
16	stderr	4	0	3	5.0408057116
17	lcl	5	0	3	125.12020235
18	ucl	6	0	3	144.87979765

The sequence displayed in Output 6.2.1 was obtained by using the SORT procedure to sort the data in the OUTNVP table in increasing order of the columns _VIX_ (that is, the series row index) and _CALL_ (that

is, the OUTNVP object's Collect method call count within BY group). For example, rows 1–6 contain the values of the first observation in each of the six collected series, which correspond to the rows in the mycas.outnvpmodel CAS table where column _VIX_ = 1: row 1 is the value of the first observation in the actual Air series (that is, column _VAR_ = `'AIR'`), rows 2–3 are the values of the first observations in the simulated Predict and Error series of the ad hoc external forecast, and rows 4–6 are the values of the first observations in the StdErr, LCL, and UCL forecast series that were computed by the CLIMITS object for the ad hoc external forecast and retrieved via its GetForecast method. The same applies for the second observation in each of the six collected series as described by rows 7–12 (that is, rows where column _VIX_ = 2) and for the third observation in each of the six collected series as described by rows 13–18 (rows where column _VIX_ = 3).

Notice also in Output 6.2.1 the value of 5.0408057116, which is reported for the first three observations of the prediction standard errors series, as shown by rows where column _VAR_ = `'stderr'`. This reported value should be close to the expected value of the simulated forecast error of the synthetic external forecast (5.0).

Subject Index

Syntax Index