Rules Fest 2011
RuleBased Forecasting
Part II

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How to Find Part I

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Introduction

Our talk today will focus on Standard forecasting wherein we use different methods to try and determine the needed data.

Zen of Forecasting

Remember: **Forecasting can NEVER become a substitute for prophecy**. "… *no* statistical method… allows us to accurately forecast … the extent of future uncertainty when "history does not repeat itself."
(MAK98, p.550)

Forecasting Works With Data

- If you need to know the data for the next few weeks, months or even years, you have to know the kind of forecasting that you must use.
  - Standard Forecasting
  - Regression
  - Econometric
  - Neural Net
  - etc.

Exploring the Kinds of Data

- A: If the data are **flat**, forecasting is easy
- B: If the data are **steadily increasing or decreasing**, again, it's easy
- C: If the data has **discernable patterns**, then we can apply various forecasting techniques
  - Seasonal
  - Cyclical
  - Trends

Some Forecasting Terms

Expert System: A model designed to represent the procedures that experts use in making decisions or forecasts.

- **Forecasting**: Estimating an unkown situation in the future.
- **F-Test**: A test for statistical significance that relies on the comparison of two MSE (Mean Square Errors or Variances)
- **MAD**: Mean Absolute Deviation – An estimate of variation that ranges from 1.0 to 1.5 in practice.
- **Cross Correlation**: The standardized measure of association between the values in one time series and those in another time series.

Some Forecasting Terms

- **Decomposition**: The process of breaking a problem into subproblems, solving them and then combining the solutions to get an overall solution.
- **Double Moving Average**: MA of a series of another MA
- **Econometric Model**: One or more regression equations to capture the relationship between dependent variable and the explanatory variables.
- **Elasticity**: Expression of the percentage of change in the variable of interest that is caused by a 1% change in another variable.

Read the books and papers for the other 3,000 terms and definitions.

Smoothing Methods

- **Single Moving Average**
- **Double Moving Average**
- **Single Exponential Smoothing**
- **Single Exponential Smoothing – Adaptive**
- **Double Exponential Smoothing**
  - Brown's One-Parameter Linear Model
  - Holt's Two Parameter Method
  - Brown's One Parameter Quadratic Method

Smoothing Methods

- **Holt-Winter's Exponential Smoothing Method**: An extension of Holt's method that includes a method to smooth seasonality
- ***ARIMA:*** **A**uto**R**egressive **I**ntegrated **M**oving **A**verage Model

Smoothing Methods (part 2)

- **Box-Jenkins**: The application of ARIMA to Time Series Forecasting
- **Holt's Exponential Smoothing Method**: An extension of a single exponential smoothing method that allows for trends in the data.
- **Triple Exponential Smoothing**
  - Winters 3-Parameter Trend and Seasonality Method
- **Exponential Smoothing**: Pegels' Classification
- **Chow's Adaptive Control Methods**
- **Brown's One-Parameter Adaptive Method**
- **Harrison's Harmonic Smoothing Method**
- **Trigg's Monitoring System** (Tracking Signal)

Example: 3/5-Month Moving Average Calculation

For the Three-Month Moving Average:
T2 = 1/3 (Y1 + Y2 +Y3) = 1/3 (266.0 + 145.9 + 183.1) = 198.3

For the Five-Month Moving Average
T7 = 1/5 (T5 + T6 + T7 + T8 + T9)
= 1/3 (180.3 + 168.5 +231.8 + 224.5 + 192.8) = 199.6

Note that as the number of periods are taken into account on a MA smoothing method, a chart of the numbers would be more and more linear.

Single Data Definitions Examples

Some Terms in Statistics / Forecasting

- Mean (average)
- Standard Deviation (variance from the mean)
- Variance
- Skewness
- RMS, Root Mean Square
- Covariance
- Correlation Coefficient ®

Data from Gas Consumption

t	X_t	X_{t-1}	$(X_t - X_{avg})$	$(X_{t-1} - X_{avg})$	$(X_t - X_{avg})^2$	(Xt - Xavg)(Xt - Xavg)	
1	52		-2.45		6.0025		
2	41	52	-13.45	-2.45	180.9025	32.9525	
3	88	41	33.55	-13.45	1125.6025	-451.2475	
4	67	88	12.55	33.55	157.5025	421.0525	
5	53	67	-1.45	12.55	2.1025	-18.1975	
6	75	53	20.55	-1.45	422.3025	-29.7975	
7	40	75	-14.45	20.55	208.8025	-296.9475	
8	49	40	-5.45	-14.45	29.7025	78.7525	
9	82	49	27.55	-5.45	759.0025	-150.1475	
10	75	82	20.55	27.55	422.3025	566.1525	
11	80	75	25.55	20.55	652.8025	525.0525	
12	26	80	-28.45	25.55	809.4025	-726.8975	
13	39	26	-15.45	-28.45	238.7025	439.5525	
14	40	39	-14.45	-15.45	208.8025	223.2525	
15	68	40	13.55	-14.45	183.6025	-195.7975	
16	39	68	-15.45	13.55	238.7025	-209.3475	
17	63	39	8.55	-15.45	73.1025	-132.0975	
18	49	63	-5.45	8.55	29.7025	-46.5975	
19	21	49	-33.45	-5.45	1118.9025	182.3025	
20	42	21	-12.45	-33.45	155.0025	416.4525	
Average t =	**54.45**			**Sum =**	**7022.95**	**628.4475**	**= Sum**

Covariance & AutoCovariance

Auto-Cov(1) = [1 / (20-1-1)] * 628.45 = 34.91

AutoCorr(1) = (628.45) / (7022.95) = 0.09

[Covariance] $Cov_{xy} = 1/(n-1)\ \Sigma(X_i - X_{avg})(Y_i - Y_{avg})$

[Correlation] $r_{xy} = Cov_{xy} / (S_x S_y)$

Steps for a Forecasting Project

(83Mak-p67)

1. Choose (rules?) a time series data set. Divide into initialization set and test set

2. Choose (rules?) Choose Smoothing method

3. Initialize the Method

4. Use the smoothing to forecast over the "Test" set using the MAPE and/or MSE to check errors.

5. Optimize

6. Appraisal
    1. Pros & Cons
    2. Appraisal Potential

7. Compare various smoothing Methods

Steps for a Forecasting Project

Way back in 1961 Brown and Myer showed that for any time series such that X_t (where t = 0,n-1,n) that there exists at time t a unique Polynomial representing the time series.

$$F_{t+m} = a_t + b_t m + (C_t / 2)m^2 + \ldots + (g_t/k)m^k$$

See also Brown & Myer, 1961, pp 638-685, presented at the 10th National Meeting of Operations Research (OR) Society of America at San Francisco, Nov 16, 1956.

Steps for a Forecasting Project

Early Foundations of a Forecasting Project (Arm p8)

1. Correct Bias in Judgmental Forecasting
2. Forecasts provided by efficient markets are optimized
3. Use the longest time series available
4. Econometric forecasting should be **fairly simple**
5. DO NOT use judgment to revise predictions from cross-sectional forecasting methods.
6. Theory should precede Analysis of data in developing econometric methods

Forecasting from Intentions

1. **How** should Intentions be Measured?
    1. Use probability scales to measure individuals' predictions
    2. Instruct respondents to focus on their OWN characteristics
2. **How** should Intentions be used to Forecast Behavior?
    1. Do not accept intentions data at face value
3. **How** should Intentions be Adjusted When Using Data About Behavior
    1. Use data about past participation in a behavior to adjust intentions behavior
    2. Segment respondents prior to adjusting intentions
    3. For best- and – worst-case situations, use intentions to determine bounds
4. **When** should Intentions Be Used To Predict Behavior?
    1. Place more reliance on predictions from intentions for behaviors
5. **Why** Are Intentions Sometimes Biased Measures of Behavior?
        - Be aware that measuring intentions can change behavior
        - Be aware that respondents who recall the time of last purchase might be mistaken on their future purchases(2005Arm, pp 34+)

Forecasting from Intentions

Forecasting from Intentions Data (2005Arm, pp 34+)

(some personal notes)

1. Respondents must WANT to respond AND respond properly (p41)
2. (Example) Will you chew gum or smoke cigarettes in the future? (p45)
3. It would be useful in the future if research provided better and further direction when testing respondents in answering questions so that we can minimize bias. (p53)

Delphi Technique

(2005Arm, pp 125+)

When using the Delphi technique, one person controls the exchange of information between anonymous panelists over a number of round (iterations), taking the average of the estimates on the final as the group judgment.

There are usually five to twenty experts with disparate backgrounds. But, remember we are talking EXPERTS and not beginners nor junior developers.

Usually there are only two or three rounds using feedback to each expert to help reach agreement.

Delphi Technique

Delphi Technique (2005Arm, pp 127+)

1. Use Experts with appropriate domain knowledge.
2. Use heterogeneous (same field of expertise) experts
3. Use between 5 and 20 Experts
4. For Delphi feedback, provide the mean or media (average) estimate of the panel plus the rationales from all panelists for their estimates.
5. Continue Delphi poling until the responses show stability; generally three structured rounds are enough.
6. Obtain the final forecast by weighing all the experts' estimates and aggregating them.
7. In phrasing questions, use clear and succinct definitions and avoid emotive terms.
8. Frame questions in a balanced manner – ordering of questions is important.
9. Avoid incorporating irrelevant information in the questions
10. When possible, give estimates of uncertainty **as frequencies** rather than probabilities or odds.
11. Use coherence checks when eliciting estimates of probabilities.

RuleBased Forecasting

The *IF* (Conditional or LHS) part of the rules has several possible conditions that rely on domain knowledge (p263)

- Information about the expected functional form
- Cycles (not seasons)
- Whether the series represents a startup or not
- The forecasting horizon, short or long term
- Historical adjustments of observations due to unusual events
- What factors might be affecting Trend

Armstrong (p267) estimates that there are perhaps over a billion types of series depending on the data and conditional elements.

RuleBased Forecasting

RuleBased Forecasting (2005Arm, pp 262+)

The ***Then (action)*** part of the rules several points that should be examined (p267)

- **Use** full trend extrapolation for reinforcing series
- Place only a little weight on the trends in contrary series
- If expected trends (from casual forces) are contrary to historically estimated trends, then do not use the historical trend.
- Use a conservative trend estimate if the basic and recent trends are inconsistent.
- Tailor extrapolation weights to the time interval series.
- To estimate levels for the short-term model, heavily weight the latest observations, particularly in the presence of discontinuities.
- Adjust the estimate of the level in the direction implied by the casual forces.

RuleBased Forecasting

RuleBased Forecasting Findings (2005Arm, p273)

Because RBF is designed to tailor the extrapolation to the features, Armstrong et al expected it to be more accurate than traditional methods in many situations. Their major findings were that RBF improves accuracy ONLY when:

- **Long-Interval (e.g. annual) data are used**
- **Good domain knowledge is available**
- **Casual forces can be clearly identified**
- **Domain knowledge conflicts with historical trend**
- **Long-range forecasts are needed**
- **Significant trends exist**
- **Uncertainty is modest to low**
- **Instability is modest to low**

RuleBased Forecasting

RuleBased Knowledge Acquisition (2005Arm, p287+)

Knowledge Acquisition procedures for developing expert systems

Procedure	Percentage of Developers Using
Interviewing Experts	100
Literature Reviews	---
Questionnaires	---
Taking Experts through case studies	28
Use of Inductive technique	18
Retrospective process tracing	---
Recording experts at work (protocols)	16

RuleBased Forecasting

A Strategy for Econometric Forecasters (Arm p307+)

- Define the objectives of the modeling effort
- Determine the et of variables to use based on economic theory and previous work.
- Collect the data, generally as long a time series as possible
- Form an initial specification of the model
  - Each variable is in turn the dependent variable in the equation and its lagged values are explanatory variables in each equation.
  - A general to specific modeling strategy is followed
  - The problem of forecasting is the casual variables is solved internally
  - For any variable, one possible specification is a univariate model
- Estimate the Model
- Assess model adequacy by conducting misspecification tests
- Compare the out-of-sample performanse of the final model or models against the performance of a benchmark model.

RuleBased Forecasting

A Strategy for Econometric Forecasters (Arm p.310)

- Statistical significance, unfortunately, is often assumed to represent importance. McCloskey and Zilak (1996) found that the authors of most econometrics textboooks and even of articles in the prestigious *American Economic Review* ignored or glossed over the distinction between economic significance and and statistical significance .
- An economically significant variable is one whose coefficient is sufficiently large that the favorable contributes substantially towards explain the value of the dependent variable.
- Economic significance is insufficient justification for keeping a variable in a forecasting model.

RuleBased Forecasting

ORF 2011 – Forecasting Part 2

Example Rule in C/C++

```
/*============Random Walk ================ ForecastModels.cp
*/
void NaiveForecast(float Series[], float Forecasts[], int
NumberOfPoints, FORECASTS *EstimatePtr, FEATURES
*FeaturePointer)
{
int i = 0;
float Level = 0.0,Trend = 0.0;
Level = Series[NumberOfPoints-1];
for (i = 0; i < FORECAST_PERIOD; i++)
{
        Forecasts[i] = Level;
        rintf("Naive Forecast\t%f/n", Forecasts[i]);
}
EstimatePtr->RWTrend = 0;
if (FeaturePointer->FunctionalForm == 1)
        EstimatePtr->RWLevel = log(Level);
elseEstimatePtr->RWLevel = Level;
printf("RW Level\t%f/n", EstimatePtr->RWLevel);
}
```

RuleBased Forecasting

ORF 2011 – Forecasting Part 2

Example Rule in C/C++

Estimate Pointer rule in C/C==

```
EstimatePtr->RWTrend = 0;
if (FeaturePointer->FunctionalForm == 1)
     EstimatePtr->RWLevel = log(Level);
elseEstimatePtr->RWLevel = Level;
printf("RW Level\t%f/n", EstimatePtr-
>RWLevel);
}
```

RuleBased Forecasting

Example Rule in C/C++ Rules

```
rule estimatePointer
if EstimatePtr.RWTrend == 0;
     featurePointer->FunctionalForm == 1;
     estimatePtr.RWLevel = log(Level;
do  { estimatePtr.RWLevel = Level;
}
else {
     printf("RW Level\t%f/n" +
estimatePtr.RWLevel);
}
```

RuleBased Forecasting

A Rule in C/C++ for Random Walk Process

```
/*============Random Walk ================ ForecastModels.cp
*/
void NaiveForecast(float Series[], float Forecasts[], int
NumberOfPoints, FORECASTS *EstimatePtr, FEATURES
*FeaturePointer)
{
int i = 0;
float Level = 0.0,Trend = 0.0;
Level = Series[NumberOfPoints-1];
for (i = 0; i < FORECAST_PERIOD; i++)
{
        Forecasts[i] = Level;
        rintf("Naive Forecast\t%f/n", Forecasts[i]);
}
EstimatePtr->RWTrend = 0;
if (FeaturePointer->FunctionalForm == 1)
        EstimatePtr->RWLevel = log(Level);
elseEstimatePtr->RWLevel = Level;
printf("RW Level\t%f/n", EstimatePtr->RWLevel);
}
```

RuleBased Forecasting

Same Rule in OPSJ for Random Walk Process

```
rule RandomWalk
{
if
        lev : (Level );
        f : Forecast ( value == lev.getValue() );
        rw : RWLevel ( var ll = log.get(level);
[1]     ff : FunctionalForm (value == 1);
}
do
{       System.out.println("Naive Forecast” +\t +%f +\n
+f.getvalue() );
        Estimate.setRWTrend (0);
} else(1) {
        rw.setValue ( f.getLevel() );
        System.out.println("RW Level” + \t +%f +\n
+f.getValue()  );
}
```

RuleBased Forecasting

Appendix A1: References

Books

•**Principles of Forecasting**, *A Handbook for Researchers and Practioners,* Kluwer Academic Publishers, J. Scott Anderson - Fred Colopy and Monica Adya, editors, ISBN 0-7923-7930-6,

•Principles of Forecasting, 3rd Printing, Compilation of many authors edited by J. Scott Armstrong, ISBN 0-7923-7930-6

•Time Series Forecasting, Bruce L. Bowerman & Richard T. O'Connel, ISBN 0-87150-070-0

•Demand-Driven Forecasting: A Structured Approach to Forecasting,Charles W. Chase, Wiley (SAS Books), ISBN 978-0-470-41502-3

•T. M. O'Donovan, Short Term Forecasting: An Introduction to the Box-Jenkins Approach, ISBN 0-471-90013-3

•Forecasting Methods and Applications (2nd Edition), Sypros Makridakis, Steven C. Wheelwright and Victor E. McGee, ISBN 0-471-08610-X

•Forecasting Methods and Applications (3rd Edition), Sypros Makridakis, Steven C. Wheelwright and Rob J. Hyndman, ISBN 978-0-471-53233-0

•Forecasting Methods for Management,Steven C. Wheelwright & Sypros Makridakis, 4th Ed, ISBN 0-471-81687-6

RuleBased Forecasting

Appendix A2: More References

White Papers

• Batory, Don and Marty Sirkin: "Reengineering a Complex Application Using a Scalable Data Structure Compiler.}

• Collopy, Fred and J. Scott Armstrong: "**Rule-Based Forecasting and Validation of an Expert Systems Approach to Combining Time Series Extrapolations."**

• Richard Hicks: "Exhaustive Verification of Propositional Logic Rulebases."

• Jan Vanthienen, "Ruling the Business: About Business Rules and Decision Tables."

• "Research of Intelligent Rule-base Based on Multilayer Intrusion Detection."

• "Exhaustive Verification of Propositioinal Logic Rulebases", Richard C. Hicks, International University Department, Texas A&M

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Questions?

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