

RuleBased Forecasting

Mostly this presentation extends a previous work by Drs. Armsrong, Collopy and Adya, Published in 1992 but includes input from many of the references, books and white papers.

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)

RuleBased Forecasting

Commercial Forecasting

[MAK₉₈]

- Short-term Forecasting (1 week to 1 month)
 - Do I have enough material for one-week's production run?
 - Do I have enough people for this week?
 - Seasonality

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Commercial Forecasting

[MAK₉₈]

- Mid-Range Forecasting (1 month – 1 year)
 - Do we have enough projected profit to pay all expenses for this year?
 - Do we need more workers, cash, credit, what to make it to the end of the year?
 - Recessions and booms ?
 - Depression?
 - Contingency Planning

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Commercial Forecasting

[MAK₉₈]

Long-Range Forecasting (1 year – 5 years)

- Is my CxO good enough to last the next 5 years
- If not, who can we get to replace that particular CxO?
- What can I do to change the board of directors?
- What company can we buy/sell to improve our financial status?
- MegaTrends, Analogies, Scenarios
- Ever-moving Technologies
- Organizational Consensus

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Some things that can and can NOT be predicted:

[MAK98]

Yes:

- Empirical Evidence
- Historical Events Repeating themselves
- Expenses & Income if nothing “extra ordinary” happens

No:

- Optimism
- Recency Bias (or any kind of bias for that matter)
- Floods if you are not in a 100 year flood plain
- Wars
- Gut Feelings (Good or bad)

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Organizational Aspects – The Preparer:

[MAK₉₈]

Preparer's Ability

- Understand sophisticated mathematical forecasting tendencies
- Understand management Problems
- Provide forecasts in new situations
- Provide forecasts in on-going situations
- Identify important issues in forecasting situation
- Identify the best technique for a given situation
- Provide cost-effective forecasts
- Provide results in the time frame required

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Organizational Aspects – The User:

[MAK₉₈]

User's Technical Ability

- Understand the essentials of forecasting techniques
- Understand sophisticated mathematical forecasting techniques
- Identify new applications for forecasting
- Effectively use formal forecasts
- Evaluate the appropriateness of forecasting technique

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Organizational Aspects – The User/Preparer Interaction Skills:

[MAK₉₈]

User/Preparer Interaction Skills

- Understand management problems (preparers)
- Work within the organization (preparers)
- Communicate with preparers of forecasts (users)
- Work within the organization in getting forecasts (users)

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Types of Forecasting Problems and Their Solutions

[MAK₉₈]

- Characterize Problems
- Credibility and Impact
- Lack of recent improvements in forecasting (RBF should help)
- Lack of a firm base on which to build
- Major opportunities for improvement
- Training
- Pitfalls

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Forecasting Problems and Their Solutions: Problems

[MAK98]

- Credibility and impact
- Lack of recent improvement
- Lack of firm base on which to build
- Inadequate training

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Forecasting Problems and Their Solutions: **Credibility and Impact**

[MAK₉₈]

- Forecasting often has little impact on decision making
- Forecast may have a lack of relevance
- Problems may be interpersonal
- Forecasters seem to focus on well-behaved situations
- Forecasts should be dynamic and adapt to change
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Forecasting Problems and Their Solutions: Improvement

[MAK98]

- Organizations “feel” that more could be done
- Is the forecasting extremely vulnerable to changes in environment
- Are changes in strategy required or needed?
- Major opportunities or improvement internally
- Benchmark the firms performance with various criteria

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Forecasting Problems and Their Solutions: Training

[MAK98]

- Emphasis should NOT be on the forecaster's knowledge; rather:
 - How to select a time horizon
 - How to choose a time period
 - How to find the “appropriate” data
 - Adjust data for outliers and other possible errors
 - How can large changes be monitored and adjusted
 - Level of aggregation

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Forecasting Problems and Their Solutions: Pitfalls

[MAK98] [Armstrong]

- Access the methods without the forecasts.
 - Forecasts independent of top management?
 - Forecast used objective methods?
 - Structured Techniques used to obtain data
- What assumptions have to be made?
 - Ample budget for analysis and presentation of data? (Costs)
 - Central Data Bank with years of history
- Assessment of uncertainty.
 - Upper and lower bounds provided?
 - Quantitative analysis of previous accuracy?
 - Forecasts prepared for alternative futures?
 - Arguments listed against each forecast?
- Assessment of costs – is the amount spent “reasonable”?
- Forecasting Methods
- Assumptions and Data
- Uncertainty
-

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Monday Morning Quarterback Problem

- IBM did not buy MS software (Why?)
- Creative insights
- Hindsight versus foresight
- Makridakis wrote in 1996 that Java “...is not even known at present but will undoubtedly become a huge commercial success in the future precisely because of the creative insights of some people who can conceive their commercial value and take specific steps to exploit them to their advantage. [MAK98, p.570]

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We are always forecasting on a personal basis!!

- Do we need to stop for gas? (How much gas is left?)
- Will it rain today? (I might need my umbrella)
- Will we need more employees next quarter/year?
- When should we plant the soy beans? (farmer)
- Should I buy/sell IBM stock? (If so, how much?)

And it all depends on rules of one kind or another!

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First: Why do we need forecasting?

- Farmers: When to plant
- Banks: What is the “best” interest rate for this loan
- Brokers: Which stock to sell/buy and WHEN
- Doctors: Diagnostics
- Markets: How much to move where and when

Next: Let's get some terms and conditions out of the way – terms that forecasters will use and that you, if you are going to write rules for them, should know:

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For mean coverage, the condition is that the data MUST be stationary, a term meaning that the process generating the data is in equilibrium around a constant value (the underlying mean) AND that the variance around the mean remains constant over time.

This means that you have to remove any Trend, Seasonal influence, cycles, etc. from the data, do the forecasting using various smoothing and mathematical routines, and then reverse the process to obtain the next needed datum point.

RuleBased Forecasting - MA

Month	Time Per.	Obs Value	3-Mo MA	5-Mo MA
Jan	1	266.0	...	...
Feb	2	145.9	198.3	...
Mar	3	183.1	149.4	178.9
Apr	4	119.3	160.9	159.4
May	5	180.3	156.0	176.6
Jun	6	168.5	193.5	184.9
Jul	7	231.8	208.3	199.6
Aug	8	224.5	216.4	188.1
Sep	9	192.8	180.1	224.7
Oct	10	122.9	217.4	212.5
Nov	11	336.5	215.1	206.5
Dec	12	185.9	238.9	197.8
Jan	13	194.3	...	...
Feb	14	149.5	...	...
...				

RuleBased Forecasting - MA

Previous slide from [MAK98, p.91]

Note:

For the **Three-Month Moving Average**:

$$T_2 = 1/3 (Y_1 + Y_2 + Y_3) = 1/3 (266.0 + 145.9 + 183.1) = 198.3$$

For the **Five-Month Moving Average**

$$\begin{aligned} T_7 &= 1/5 (T_5 + T_6 + T_7 + T_8 + T_9) \\ &= 1/5 (180.3 + 168.5 + 231.8 + 224.5 + 192.8) = 199.6 \end{aligned}$$

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.

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Normal Forecasting

- Choose the data set and the test set
- Choose the “smoothing” method (more on that later)
- Initialize the method
- Use the smoothing method on the test data
- Check the MAPE, MSE, SD, etc. (See Appendix C for these)
- Optimize (Search for an optimum values of the parameters)
- Reach a decision.

(Note that most of these steps involve rules of one kind or another)

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Smoothing Method Title	Smoothing Method Title
The Mean (Average)	Triple Exponential (Winter's Three-Parameter)
Single Moving Average	Triple Exponential, Trend and Seasonality
Double Moving Average	Pegel's Classification
Single Exponential	Chow's Adaptive
Double Exponential	Brown's One-Parameter Adaptive
Adaptive Single Exponential	Box-Jenkins One-Parameter Adaptive
Double Exponential (Brown's One-Parameter Linear)	Harrison's Harmonic Smoothing
Double Exponential (Holt's Two-Parameter Method)	Trigg's Monitoring (Tracking) Signal
Triple Exponential (Brown's One-Parameter Quadratic)	

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Decomposition Methods

$$X_t = f (I_t , T_c , T_t , C_t , E_t)$$

- X_t = Time Series Value @ period t
- I_t = Seasonal Component
- T_c = Trend Component
- C_t = Cyclical Component
- E_t = Error (Variance) Component

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Seasonality

Normally we think of four seasons :

- Spring
- Summer
- Fall
- Winter

BUT

Clothing could follow three seasons

Winter (Oct – Feb) , Spring (Mar – June) and Summer (July – Sept)

Construction could have two seasons

Main (Apr – Oct), Secondary (Nov – Mar)

Farming could have five seasons

Preparation, Planting, Maintenance, Harvest, Layby

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Trend Calculation Methods

$$\bar{X} = \frac{\sum_{i=1}^n X_n}{n}$$

$$X_t = a + b^t$$

$$b = \frac{n \sum tx - \sum t + \sum x}{n \sum t^2 - (\sum t)^2}$$

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Various Decomposition Methods

Additive

$$X_t = (I_t + T_t + C_t) + E_t$$

Multiplicative (Census 2)

$$X_t = I_t * T_t * C_t * E_t$$

Where

X_t = Datum at some point in time

I_t = Seasonal influence at some point in time

T_t = Trend Influence at some point in time

C_t = Cyclical influence at some point in time

E_t = Forecast Error at some point in time

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Various Decomposition Methods

Moving Average 3x3

$$M_2 = (X_1 + X_2 + X_3) / 3 \text{ (Remember we did this one?)}$$

Likewise there is an M_3 and an M_4

So then:

$$M_{3 \times 3} = (M_2 + M_3 + M_4) / 3$$

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FORECASTING AND RULES

English:

Rule4. *Last Observation Unusual.*

IF the last observation is unusual,
THEN replace it by - the average of the last observation
AND the rule-based forecast for this period that was made
at $t-1$.

{The last observation is especially important. This rule reduces
the impact of the last observation when it is subject to much
uncertainty.}

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FORECASTING AND RULES

Pseudo Code:

Rule4. *Last Observation Unusual (Outliers)*
{fire once for each datum}.

IF (X_t is $> X_AVG_t * 400$)
(OR X_t is $< X_AVG_t * 400$)

THEN $X = (X_AVG_{t-1} + X_FCST_{t-1}) / 2$

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FORECASTING AND RULES

Pseudo Code:

Rule4. *Last Observation Unusual (Outliers)*
{fire once for each datum}.

IF X_t is $> X_AVG_t * OUTLIER_NUM$
OR X_t is $< X_AVG_t * OUTLIER_NUM$

THEN $X = (X_AVG_{t-1} + X_FCST_{t-1}) / 2$

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Appendix A1: References

Books

- [ARM2001] Principles of Forecasting, 3rd Printing, Compilation of many authors edited by J. Scott Armstrong, ISBN 0-7923-7930-6
- [BOW87] Time Series Forecasting, Bruce L. Bowerman & Richard T. O'Connel, ISBN 0-87150-070-0
- [CHA2009] Demand-Driven Forecasting: A Structured Approach to Forecasting, Charles W. Chase, Wiley (SAS Books), ISBN 978-0-470-41502-3
- [ODO83] T. M. O'Donovan, Short Term Forecasting: An Introduction to the Box-Jenkins Approach, ISBN 0-471-90013-3
- [MAK83] Forecasting Methods and Applications (2nd Edition), Sypros Makridakis, Steven C. Wheelwright and Victor E. McGee, ISBN 0-471-08610-X
- [MAK98] Forecasting Methods and Applications (3rd Edition), Sypros Makridakis, Steven C. Wheelwright and Rob J. Hyndman, ISBN 978-0-471-53233-0
- [WHE95] Forecasting Methods for Management, Steven C. Wheelwright & Sypros Makridakis, 4th Ed, ISBN 0-471-81687-6

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Appendix A2: References

White Papers

- [BAT94] Batory, Don and Marty Sirkin: “Reengineering a Complex Application Using a Scalable Data Structure Compiler.”
- [COL92] Collopy, Fred and J. Scott Armstrong: “Rule-Based Forecasting and Validation of an Expert Systems Approach to Combining Time Series Extrapolations.”
- [HIC99] Richard Hicks: “Exhaustive Verification of Propositional Logic Rulebases.”
- [VAN96] Jan Vanthienen, “Ruling the Business: About Business Rules and Decision Tables.”
- [ZHI04] “Research of Intelligent Rule-base Based on Multilayer Intrusion Detection.”
- [HIC99] “Exhaustive Verification of Propositional Logic Rulebases”, Richard C. Hicks, International University Department, Texas A&M

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Appendix B1

Commonly-Used Abbreviations and Formulae

PE: Percentage of Error

$$PE_t = [(X_t - F_t) / X_t] * 100$$

MPE: Mean Percentage of Error

$$MPE_t = \{ [(X_t - F_t) / X_t] * 100 \} / t$$

MAPE: Mean Absolute Percentage of Errors

$$MAPE_i = \{ \sum_{i=1}^n |PE_i| / n \}$$

SD: Standard Deviation

$$SD = \{ (1/(n-1)) \sum (x - x')^2 \} \text{ where } x' = \text{Mean}$$

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Appendix B2

Commonly-Used Abbreviations and Formulae

RMS: Root Mean Squared

$$\{ 1 / (n-1) * \Sigma (x_i - x')^2 \}$$

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Appendix C: A 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;
    printf("Naive Forecast\t%f/n", Forecasts[i]);
}
EstimatePtr->RWTrend = 0;
if (FeaturePointer->FunctionalForm == 1)
    EstimatePtr->RWLevel = log(Level);
else EstimatePtr->RWLevel = Level;
printf("RW Level\t%f/n", EstimatePtr->RWLevel);
}
```

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Appendix D1: More Terms

- **ARIMA**: AutoRegressive Integrated Moving Average Model
- **Box-Jenkins**: The application of ARIMA to Time Series Forecasting
- **Cross Correlation**: The standardized measure of association between the values in one time series and those in another time series.
- **Decomposition**: The process of breaking a problem into subproblems, solving them and the 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.

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Appendix D2: More Terms

- **Expert System**: A model designed to represent the procedures that experts use in making decisions or forecasts.
- **Forecasting**: Estimating an unknown situation in the future.
- **F-Test**: A test for statistical significance that relies on the comparison of two MSE (Mean Square Errors or Variances)
- **Holt's Exponential Smoothing Method**: An extension of a single exponential smoothing method that allows for trends in the data.
- **Holt-Winter's Exponential Smoothing Method**: An extension of Holt's method that includes a method to smooth seasonality.
- **MAD**: Mean Absolute Deviation – An estimate of variation that ranges from 1.0 to 1.5 in practice.
- (read the books and papers for the other 3,000 terms and definitions)