Operational Forecasting

Decisions that Need Forecasts

- Which markets to pursue?
- What products to produce?
- How many people to hire?
- How many units to purchase?
- How many units to produce?
- And so on……

- Forecast: A statement about the future
  - Not necessarily numerical

7 R

Right product
Right Quantity
Right Place
Right time
Right Price
Right condition
Right consumer

Most recent forecasting based business cases

No rice in Japan's supermarkets. What led to the unprecedented shortage

The Japanese government warned people against panic buying of rice on Tuesday. Japan's farm minister Tetsushi Sakamoto advised the people to stay calm and said that the shortage situation would be resolved soon.

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Business Market Intelligence News Services More

Crisis in Bangladesh: A turning point for global apparel supply chains

14 Aug '24 • 11 min read

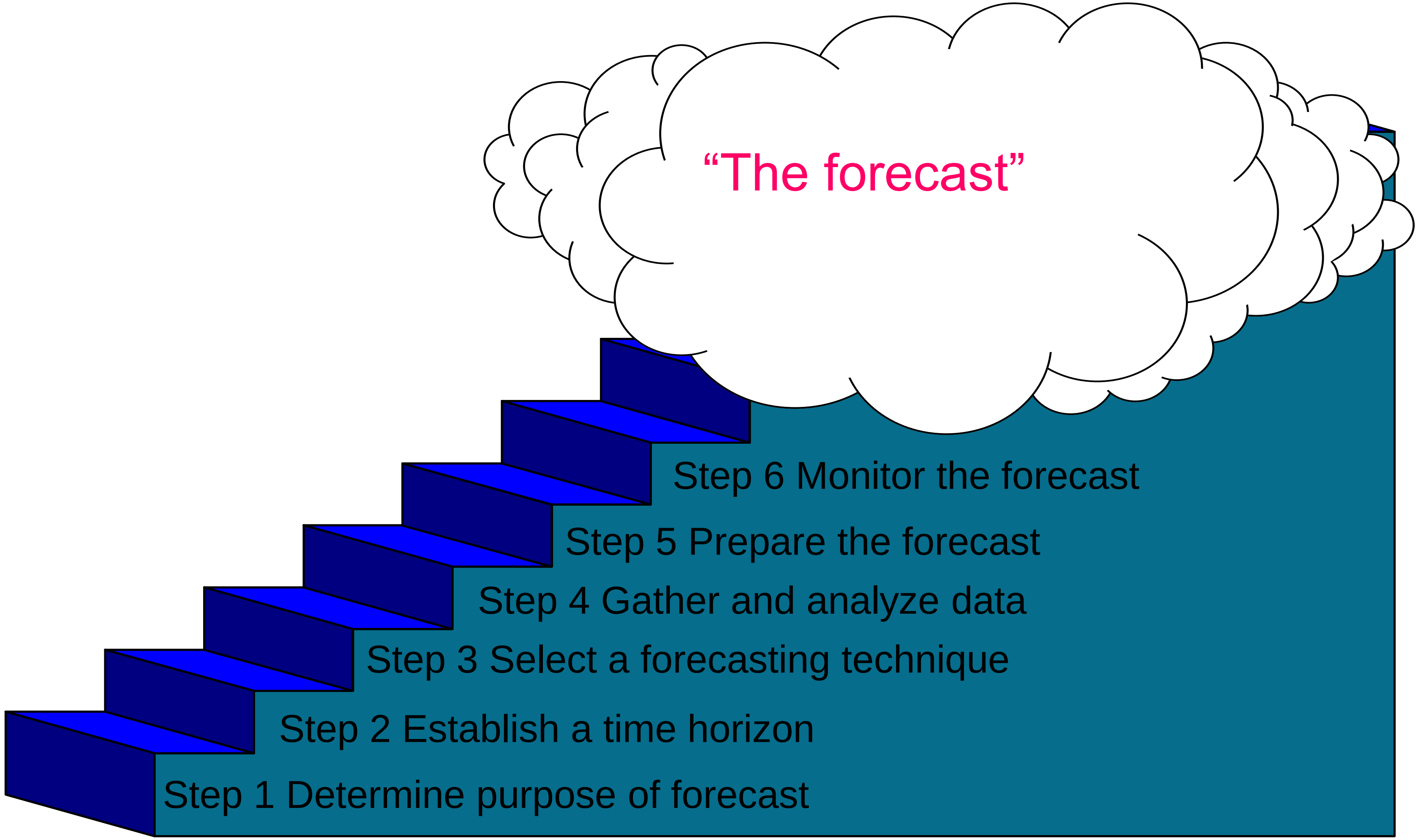
Important Points

- Assume a causal system
  - Future resembles the past
- **Forecasts rarely perfect because of randomness**
- Forecasts more accurate for groups vs. individuals.
  - Forecasting errors among items in a group usually have a canceling effect.
  - Extremes in a group cancel each other
- Forecast accuracy decreases as time horizon for forecasts increases
    - Ex. I can forecast this year’s class average better than next year’s class average

Uses of Forecasts

Accounting	Cost/profit estimates
Finance	Cash flow and funding
Human Resources	Hiring/recruiting/training
Marketing	Pricing, promotion, strategy
MIS	IT/IS systems, services
Operations	Schedules, MRP, workloads
Product/service design	New products and services

Steps in the Forecasting Process



Types of Forecasts

- *Judgmental* - Subjective analysis of subjective inputs
- *Associative models* – Analyzes historical data to reveal relationships between (easily or in advance) observable quantities and forecast quantities. Uses this relationship to make predictions.
- *Time series* – Objective analysis historical data assuming the future will be like the past

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Forecasting Steps

- What needs to be forecast?
  - Level of detail, units of analysis & time horizon required
- What data is available to evaluate?
  - Identify needed data & whether it’s available
- Select and test the forecasting model
  - Cost, ease of use & accuracy
- Generate the forecast
- Monitor forecast accuracy over time

Methods of Forecasting the Level

- Naïve Forecasting
- Simple Mean
- Moving Average
- Weighted Moving Average
- Exponential Smoothing

Judgmental Forecasts

- Executive opinions (long-range planning)
  - There are factors hard to quantify
    - Ex: Effects of November 2004 election on new houses built in 2005
- Sales force composite
  - Retailer forecasts for the manufacturer
- Consumer surveys
  - The guy at the mall who asks if you like cherry flavor in your shampoo
- Outside opinion
  - Financial and consulting gurus and companies
- Opinions of managers and staff
  - Delphi method: A series of questionnaires developed sequentially

Associative Forecasting

- Based on identification of related variables that can be used to predict values of the variable of interest.
  - Sales of mountain bikes in an area may be related to the percentage of the young population living in that area.
  - Ice cream sales can be related to temperature
  - Home depot bases sales forecasts on mortgage refinancing rates, smaller rates imply higher sales.
  - Changes in Federal Reserve Board’s interest rate leads to certain business activities
    - House sales
    - Industrial investments
  - Increase in energy cost leads to price increases in products and services

Associative Forecasting

- Find an association between the predictor and the predicted
- *Predictor variables* - used to predict values of variable interest, sometimes called independent variables
- Predicted variable = Dependent variable
- *Regression* - technique for fitting a line to a set of points
- Linear regression is the most widely used form of regression
  - The objective is to obtain an equation of a straight line that minimizes the sum of squared vertical deviations of data points from the line.

Moving Average

Next period's forecast = simple average of the last N periods

$$F_{t+1} = \frac{A_t + A_{t-1} + \dots\dots\dots + A_{t-N+1}}{N}$$

The Effect of the Parameter N

- A smaller N makes the forecast more
  responsive
- A larger N makes the forecast more
  stable

Weighted Moving Average

$$F_{t+1} = C_1 A_t + C_2 A_{t-1} + \ldots\ldots\ldots + C_N A_{t-N+1}$$

where

$$C_1 + C_2 + \ldots\ldots\ldots C_N = 1$$

Double Moving Average

$$Forecast = 2MA_{1,t} - MA_{2,t} + \frac{2}{m-1}\left[MA_{1,t} - MA_{2,t}\right]$$

Example 13.1 (page 535)

Computing a Simple Moving Average

The Heartland Produce Company sells and delivers food produce to restaurants and catering services within a 100-mile radius of its warehouse. The food supply business is competitive, and the ability to deliver orders promptly is a factor in getting new customers and keeping old ones. The manager of the company wants to be certain enough drivers and vehicles are available to deliver orders promptly and they have adequate inventory in stock. Therefore, the manager wants to be able to forecast the number of orders that will occur during the next month (i.e., to forecast the demand for deliveries).

From records of delivery orders, management has accumulated the following data for the past 10 months, from which it wants to compute three- and five-month moving averages.

Month	Orders	Month	Orders
January	120	June	50
February	90	July	75
March	100	August	130
April	75	September	110
May	110	October	90

Solution

- Assume a 3 or 5-month moving average

For November (3-month MA)= recent three period/3

= (90+110+130)/3 =110 orders

5-month MA= (90+110+130+75+50)/5= 91 orders

Refer, example 13.2, 50% oct data, 33% sept. data, and 17% August data. Then, 3 month WMA,

(0.5*90+0.33*110+0.17*130)=103.4 orders

Compute for Dec, Jan, Feb, and March

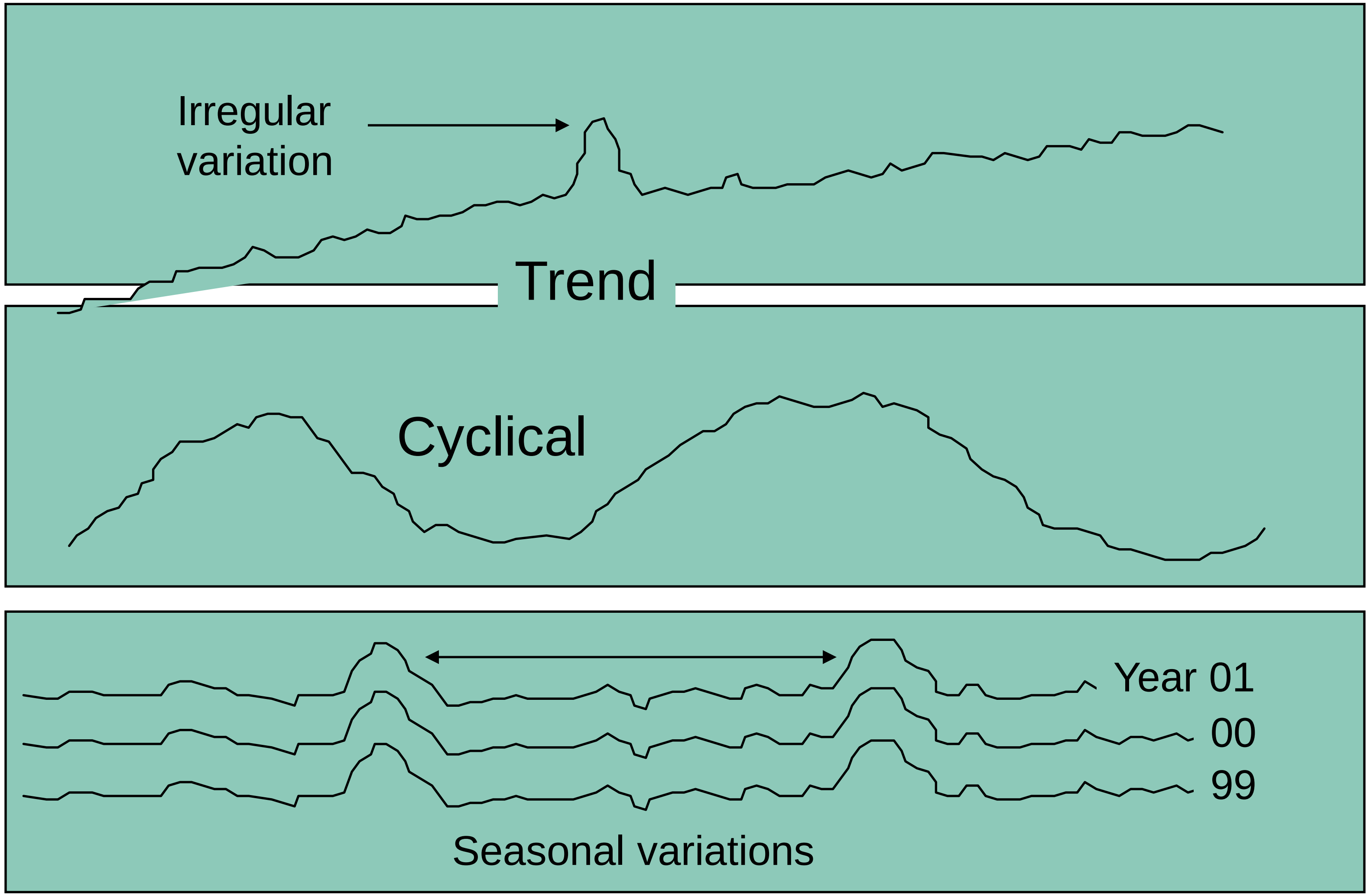
Time series

- **Time-ordered sequence of observations taken at regular intervals over a period of time**
- **Future values of the series can be estimated from past values.**

Types of Variations in Time Series Data

- *Trend* - long-term movement in data
- *Seasonality* - short-term regular variations in data
- Cycles – wavelike variations of long-term
- *Irregular variations* - caused by unusual circumstances
- *Random variations* - caused by chance

Forecast Variations



Exponential Smoothing (Page 538/Ch13)

Forecast error:=Actual – Forecast =A(t-1)-F(t-1)

$$F_t = F_{t-1} + \alpha(A_{t-1} - F_{t-1})$$

Forecast today=Forecast yesterday+(alpha)*(Forecast error yesterday)

Each new forecast is equal to the previous forecast plus a percentage of the previous error.

Today's forecast

Depends on yesterday's (time-wise dependence, strong memory)

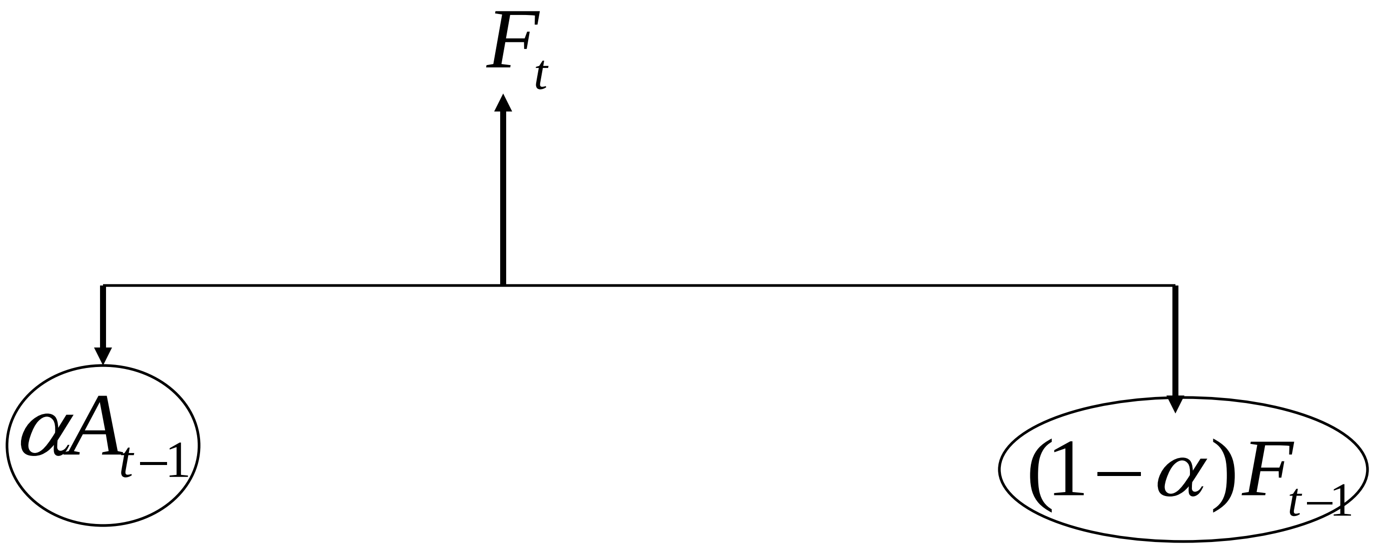
Therefore, we should give more weight to the more recent time periods when forecasting.

- Alpha = smoothing constant = percentage of the forecast error.

Exponential Smoothing as an Weighted Average

$$F_t = \alpha A_{t-1} + (1-\alpha)F_{t-1}$$

Idea--The most recent observations might have the highest predictive value along with the most recent forecast errors. Let us balance them:



Example of Exponential Smoothing

Forecasts made in a period and the period has the same color

Period	Actual	Forecast wit	Error with	Forecast wit	Error with
1	42	Alpha=0.1	Alpha=0.1	Alpha=0.4	Alpha=0.4
2	40	42	-2.00	42	-2
3	43	41.8	1.20	41.2	1.8
4	40	41.92	-1.92	41.92	-1.92
5	41	41.73	-0.73	41.15	-0.15
6	39	41.66	-2.66	41.09	-2.09
7	46	41.39	4.61	40.25	5.75
8	44	41.85	2.15	42.55	1.45
9	45	42.07	2.93	43.13	1.87
10	38	42.36	-4.36	43.88	-5.88
11	40	41.92	-1.92	41.53	-1.53
12		41.73		40.92	

$$F_t = \alpha A_{t-1} + (1-\alpha)F_{t-1}$$

HiTek Computer Services repairs and services personal computers at its store, and it makes local service calls. It primarily uses part-time State University students as technicians. The company has had steady growth since it started. It purchases generic computer parts in volume at a discount from a variety of sources whenever they see a good deal. Thus, they need a good forecast of demand for repairs so that they will know how many computer component parts to purchase and stock, and how many technicians to hire.

The company has accumulated the demand data shown in the accompanying table for repair and service calls for the past 12 months, from which it wants to consider exponential smoothing forecasts using smoothing constants (α) equal to 0.30 and 0.50.

Demand for Repair and Service Calls

Period	Month	Demand	Period	Month	Demand
1	January	37	7	July	43
2	February	40	8	August	47
3	March	41	9	September	56
4	April	37	10	October	52
5	May	45	11	November	55
6	June	50	12	December	54

Forecast Accuracy

- Forecasts are rarely perfect
- Need to know how much we should rely on our chosen forecasting method
- Measuring forecast error:

$$E_t = A_t - F_t$$

- Note that over-forecasts = negative errors and under-forecasts = positive errors

Forecast Accuracy

- Error - difference between actual value and predicted value
- Mean absolute deviation (MAD)
  - Average absolute error (weights all errors evenly)
- Mean squared error (MSE)
  - Average of squared error (weights errors according to their squared values)
- Tracking signal
  - Ratio of cumulative error and MAD

https://statxo.com/wp-content/uploads/2018/11/Case-Study-Demand-Forecasting.pdf

MAD & MSE

$$Forecast\ error = Actual - Forecast$$

$$MAD = \frac{\sum_{t=1}^{n} | A_t - F_t |}{n}$$

$$MSE = \frac{\sum_{t=1}^{n} (A_t - F_t)^2}{n-1} \approx \frac{\sum_{t=1}^{n} (A_t - F_t)^2}{n}$$

$$Tracking\ Signal = \frac{\sum_{t=1}^{n} A_t - F_t}{MAD}$$

$$\text{Estimate of (forecast error) standard deviation} = \text{s} = \sqrt{\text{MSE}}$$

$$\text{Statistics says: MSE is the unbiased estimator for the variance of forecast error.}$$

Use for MAD & MSE

- Compare the accuracy of alternative
  - **forecasting methods** using MAD and MSE.
  - **parameter (such as alpha) values** used in forecasting

  by using MAD and MSE
- Determine which method yields the lowest MAD or MSE for a given set of data.

Linear Regression (page 543)

$y = a + bx$

Where

y = predicted (dependent) variable

x = predictor (independent) variable

b = slope of the line

a = value of y when $x = 0$ (the height of line at the y intercept)

Computing a and b

Given n data points, find the intercept a and the slope b to

$$\text{Minimize} \quad \text{the sum of squared errors} =$$

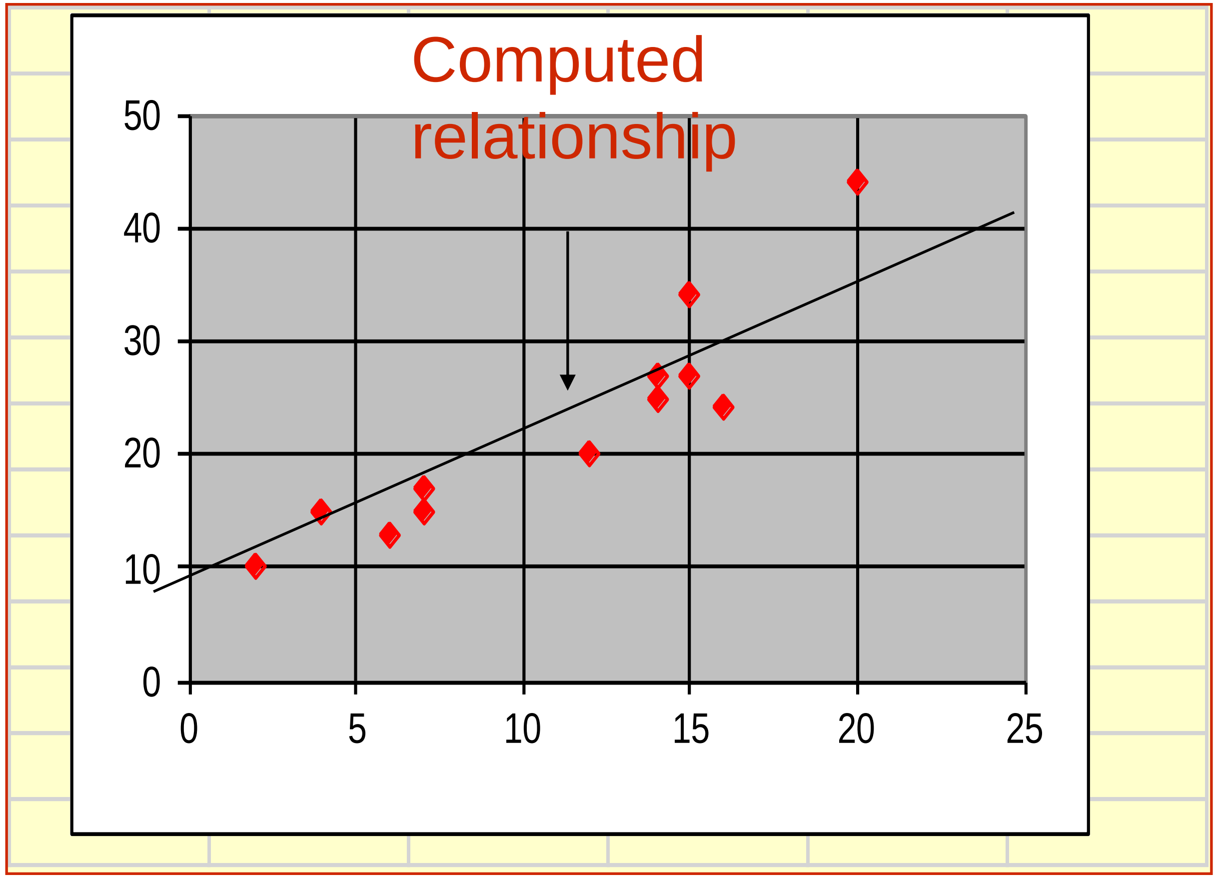
$$\text{Minimize} \quad \text{the sum of deviations from the line} =$$

$$\text{Minimize} \quad \sum_{t=1}^{n} (y_t - a - bx_t)^2$$

$$b = \frac{n\sum_{t=1}^{n} x_t y_t - \sum_{t=1}^{n} x_t \sum_{t=1}^{n} y_t}{n\sum_{t=1}^{n} x_t^{\ 2} - \left(\sum_{t=1}^{n} x_t\right)^2} \qquad a = \frac{\sum_{t=1}^{n} y_t}{n} - b\frac{\sum_{t=1}^{n} x_t}{n}$$

Linear Model Seems Reasonable

X	Y
7	15
2	10
6	13
4	15
14	25
15	27
16	24
12	20
14	27
20	44



Example Variables: Weeks and Sales

t Week	t^2	y Sales	ty
1	1	150	150
2	4	157	314
3	9	162	486
4	16	166	664
5	25	177	885
$\Sigma t = 15$ $(\Sigma t)^2 = 225$	$\Sigma t^2 = 55$	$\Sigma y = 812$	$\Sigma ty = 2499$

Linear Trend Calculation

$$b = \frac{5\,(2499) - 15(812)}{5(55) - 225} = \frac{12495 - 12180}{275 - 225} = 6.3$$

$$a = \frac{812 - 6.3(15)}{5} = 143.5$$

$y = 143.5 + 6.3\ t$

Sales in week $t = 143.5 + 6.3\ t$

$y = 143.5 + 6.3t$

When $t = 0$, the value of y is 143.45 and the slope of the line is 6.3. meaning that the value of of y will increase by 6.3 units for each time period. If $t = 10$, the forecast is $143.5 + 6.3(10) = 206.5$

Accuracy & Tracking Signal Problem: A company is comparing the accuracy of two forecasting methods. Forecasts using both methods are shown below along with the actual values for January through May. The company also uses a tracking signal with ±4 limits to decide when a forecast should be reviewed. Which forecasting method is best?

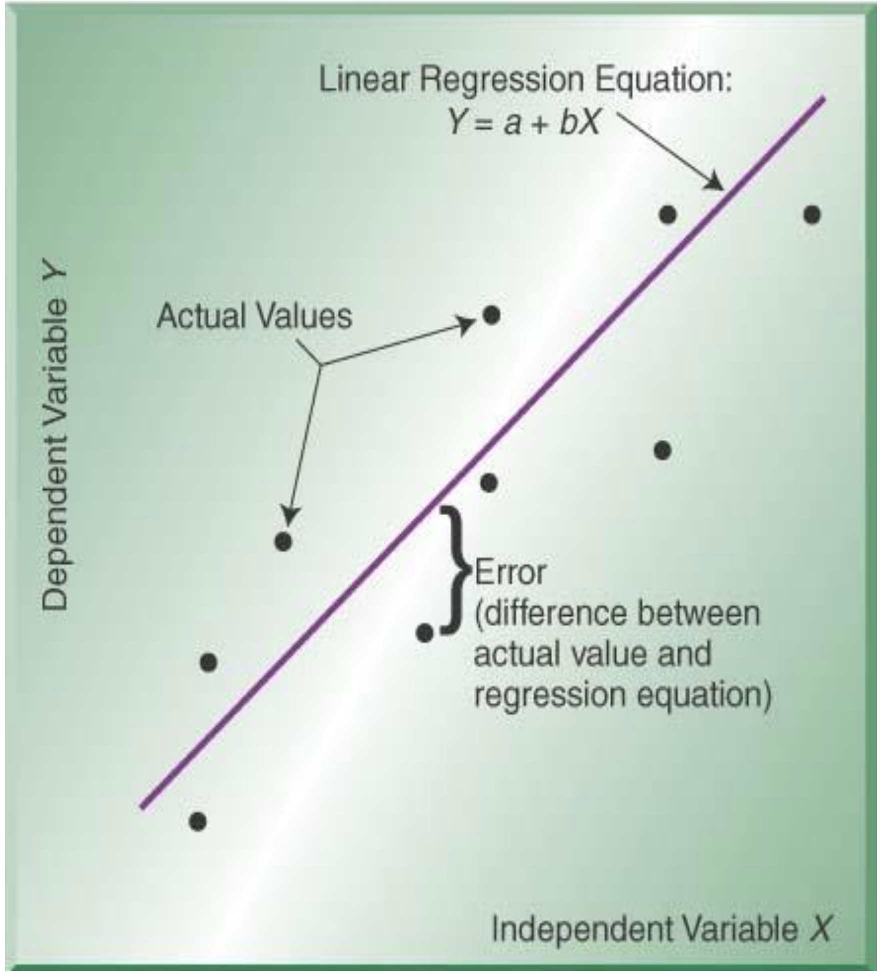
Month	Actual sales	Method A				Method B			
		F'cast	Error	Cum. Error	Tracking Signal	F'cast	Error	Cum. Error	Tracking Signal
Jan.	30	28	2	2	2	28	2	2	1
Feb.	26	25	1	3	3	25	1	3	1.5
March	32	32	0	3	3	29	3	6	3
April	29	30	-1	2	2	27	2	8	4
May	31	30	1	3	3	29	2	10	5
MAD			1				2		
MSE			1.4				4.4		

Casual Models

- Often, leading indicators hint can help predict changes in demand
- Causal models build on these cause-and-effect relationships
- A common tool of causal modeling is linear regression:

$$Y = a + bx$$

Linear Regression



- Identify dependent **(y)** and independent **(x)** variables
- Solve for the slope of the line

$$\mathbf{b} = \frac{\sum \mathbf{XY} - \mathbf{n}\overline{\mathbf{X}}\overline{\mathbf{Y}}}{\sum \mathbf{X}^2 - \mathbf{n}\overline{\mathbf{X}}^2}$$

- Solve for the y intercept

$$\mathbf{a} = \overline{\mathbf{Y}} - \mathbf{b}\overline{\mathbf{X}}$$

- Develop your equation for the trend line

Y=a + bX

Linear Regression Problem: A maker of golf shirts has been tracking the relationship between sales and advertising dollars. Use linear regression to find out what sales might be if the company invested $53,000 in advertising next year.

	Sales $ (Y)	Adv.$ (X)	XY	X^2	Y^2
1	130	48	4240	2304	16,900
2	151	52	7852	2704	22,801
3	150	50	7500	2500	22,500
4	158	55	8690	3025	24964
5	**153.85**	53			
Tot	589	205	30282	10533	87165
Avg	**147.25**	**51.25**			

$$\mathbf{b} = \frac{\sum \mathbf{XY} - \mathbf{n}\bar{\mathbf{X}}\bar{\mathbf{Y}}}{\sum \mathbf{X}^2 - \mathbf{n}\bar{\mathbf{X}}^2}$$

$$b = \frac{30282 - 4(51.25)(147.25)}{10533 - 4(51.25)^2} = 3.58$$

$$a = \bar{Y} - b\bar{X} = 147.25 - 3.58(51.25)$$

$$a = -36.20$$

$$Y = a + bX = -36.20 + 3.58x$$

$$Y_5 = -36.20 + 3.58(53) = 153.54$$

How Good is the Fit?

- Correlation coefficient **(r)** measures the direction and strength of the linear relationship between two variables. The closer the r value is to 1.0 the better the regression line fits the data points.

$$r = \frac{n\left(\sum XY\right) - \left(\sum X\right)\left(\sum Y\right)}{\sqrt{n\left(\sum X^2\right) - \left(\sum X\right)^2} * \sqrt{n\left(\sum Y^2\right) - \sum\left(Y\right)^2}}$$

$$r = \frac{(4)(30{,}282) - (205)(589)}{\sqrt{4(10{,}533) - (205)^2} * \sqrt{4(87{,}165) - (589)^2}} = .888$$

$$r^2 = (.982)^2 = .788$$

Coefficient of determination measures the amount of variation in the dependent variable about its mean that is explained by the regression line. Values of close to 1.0 are desirable.

Forecasting Software

- Spreadsheets
  - Microsoft Excel, Quattro Pro, Lotus 1-2-3
  - Limited statistical analysis of forecast data
- Statistical packages
  - SPSS, SAS, NCSS, Minitab
  - Forecasting plus statistical and graphics
- Specialty forecasting packages
  - Forecast Master, Forecast Pro, Autobox, SCA

Time Series Problem Exercise

Period	Orders (A)	Naïve Forecast	Simple Average	Simple Moving Average (N=3)	Simple Moving Average(N=5)	Weighted Moving Average (N=3)	Exponential Smoothing (α = 0.2)	Exponential Smoothing (α = 0.5)
1	122						122	122
2	91	122	122				122	122
3	100	91	107				116	107
4	77	100	104	104		102	113	104
5	115	77	98	89		87	106	91
6	58	115	101	97	101	101	108	103
7	75	58	94	83	88	79	98	81
8	128	75	91	83	85	78	93	78
9	111	128	96	87	91	98	100	103
10	88	111	97	105	97	109	102	107
11		88	97	109	92	103	99	98