Chapter 4
Data Management: Warehousing, Access and Visualization

- MSS foundation
- New concepts
- Object-oriented databases
- Intelligent databases
- Data warehouse
- Online analytical processing
- Multidimensionality
- Data mining
- Internet / Intranet / Web

4.1 Opening Vignette: Data Warehousing and DSS at Group Health Cooperative

2-3 million data records are processed monthly

- **How to manage?**
- **How to use for decision support?**
- **How to hold down costs?**
- **How to improve customer service?**
- **How to utilize resource effectively?**
- **How to improve service quality?**

Answers

- **Develop a comprehensive database (data warehouse) and DSS approach**
- **Very effective**

4.2 Data Warehousing, Access, Analysis and Visualization

What to do with all the data that organizations collect, store and use?
Information overload!

Solution

- **Data warehousing**
- **Data access**
- **Data mining**
- **Online analytical processing (OLAP)**
- **Data visualization**
- **Data sources**

4.3 The Nature and Sources of Data

- **Data: Raw**
- **Information: Data organized to convey meaning**
- **Knowledge: Data items organized and processed to convey understanding, experience, accumulated learning, and expertise**

DSS Data Items

- **Documents**
- **Pictures**
- **Maps**
- **Sound**
- **Animation**
- **Video**

Can be hard or soft

Data Sources

- Internal
- External
- Personal

4.4 Data Collection and Data Problems

- **Summarized in Table 4.1**

TABLE 4.1 Data Problems.

Problem	Typical Cause	Possible Solutions (in Some Cases)
Data are not correct.	Raw data were entered inaccurately.	Develop a systematic way to ensure the accuracy of raw data.
	Data derived by an individual were generated carelessly.	Whenever derived data are submitted, carefully monitor both the data values and the manner in which the data were generated.
Data are not timely.	The method for generating the data is not rapid enough to meet the need for the data.	Modify the system for generating the data.
Data are not measured or indexed properly.	Raw data are gathered according to a logic or periodicity that is not consistent with the purposes of the analysis.	Develop a system for rescaling or recombining the improperly indexed data.
	A detailed model contains so many coefficients that it is difficult to develop and maintain.	Develop simpler or more highly aggregated models.
Needed data simply do not exist.	No one ever stored data needed now.	Whether or not it is useful now, store data for future use. This may be impractical because of the cost of storing and maintaining data. Furthermore, the data may not be found when they are needed.
	Required data never existed.	Make an effort to generate the data or to estimate them if they concern the future.

Source: Stephen L. Alter, *Decision Support Systems*, 1980 by Addison-Wesley Publishing Company, Inc. Reprinted by permission of the publisher.

4.5 The Internet and Commercial Database Services

For External Data

- ***The Internet:*** **Major supplier of external data**
- ***Commercial Data "Banks"*****: Sell access to specialized databases**

Can add external data to the MSS in a timely manner and at a reasonable cost

DSS In Focus 4.1: Sources of External Data--A Sampler

Many sources of public data exist, some of which are available on the Internet. Common data sources are:

Federal Publications

Survey of Current Business **(Department of Commerce) (continues Business Conditions Digest in short form)--monthly, general business conditions**

Monthly Labor Review **(Department of Labor)--monthly employment statistics (a journal with articles)**

Employment and Earnings **(Department of Labor)--monthly, more detailed than Monthly Labor Review**

Other

International Monetary Fund **--report of balance of payments, including currency rates, for participating countries**

Moody's **--a series of manuals including abstracted information and balance sheets of most large U.S. corporations, intended for investors**

Standard & Poor's **--periodically updated report of financial stability of most U.S. corporations**

Advertising Age **--marketing newspaper, with a great deal of data on marketing**

Annual Editor & Publisher Market Guide **--annual report of marketing information by SMSA (standard metropolitan statistical area)**

DSS In Focus 4.1 (Cont'd)

Indexes

Business Information Sources. 1985. Rev. ed., L. M. Daniells (ed.). University of California Press. Categorization of databases by functional area of business

Encyclopedia of Business Information Sources. Updated annually. Gale Research, Inc. Bibliographic guide on about 1,000 business subjects, including online databases

Encyclopedia of Information Systems and Services. Updated annually. Gale Research, Inc. Descriptive guide to databases in electronic form

The CD-ROM Directory. Updated annually. TFPL Publishing. Index of CD-ROM databases

(*Source*: Olson and Courtney [1992], p. 119. Used with permission.)

TABLE 4.2 Representative Commercial Database (Data Bank) Services.

CompuServe and The Source. Personal computer networks providing statistical data banks (business and financial market statistics) as well as bibliographic data banks (news, reference, library, and electronic encyclopedias). CompuServe is the largest supplier of such services to personal computer users.

Compustat. Provides financial statistics about more than 12,000 corporations.
Data Resources, Inc. offers statistical data banks in agriculture, banking, commodities, demographics, economics, energy, finance, insurance, international business, and the steel and transportation industries. DRI economists maintain a number of these data banks.
Standard & Poor's is also a source. It offers services under the **U.S. Central Data Bank**.

Dow Jones Information Service. Provides statistical data banks on stock market and other financial markets and activities, and in-depth financial statistics on all corporations listed on the New York and American stock exchanges, plus 800 other selected companies. Its Dow Jones News/Retrieval system provides bibliographic data banks on business, financial, and general news from The *Wall Street Journal*, *Barron's*, the Dow Jones News Service, *Wall Street Week*, and the 21-volume *American Academic Encyclopedia*.

Interactive Data Corporation. A statistical data bank distributor covering agriculture, automobiles, banking, commodities, demographics, economics, energy, finance, international business, and insurance. Its main suppliers are Chase Econometric Associates, Standard & Poor's, and Value Line.

Lockheed Information Systems. The largest bibliographic distributor. Its DIALOG system offers extracts and summaries of more than 150 different data banks in agriculture, business, economics, education, energy, engineering, environment, foundations, general new publications, government, international business, patents, pharmaceuticals, science, and social sciences. It relies on many economic research firms, trade associations, and governmental groups for data.

Mead Data Central. This data bank service offers two major bibliographic data banks. Lexis provides legal research information and legal articles. **Nexis** provides a full-text (not abstract) bibliographic database of over 100 newspapers, magazines, and newsletters, news services, government documents, and so on. It includes full text and abstracts from the *New York Times* and the complete 29-volume *Encyclopedia Britannica*. Also provided is the Advertising & Marketing Intelligence (AMI) data bank, and the National Automated Accounting Research System.

Source: Based on Standard & Poor's Compustat Services, Inc., statistics on 6,000 companies' financial reports.

The Internet/Web and Corporate Databases and Systems

Use *Web Browsers* to

- **Access vital information by employees and customers**
- **Implement executive information systems**
- **Implement group support systems (GSS) Database management systems provide data in HTML**

4.6 Database Management Systems in DSS

- ***DBMS:*** **Software program for entering (or adding) information into a database; updating, deleting, manipulating, storing, and retrieving information**
- **A DBMS combined with a modeling language is a typical system development pair, used in constructing DSS or MSS**
- **DBMS are designed to handle large amounts of information**

4.7 Database Organization and Structure

- Relational Databases
- Hierarchical Databases
- Network Databases
- Object-oriented Databases
- Multimedia-based Databases

4.8 Data Warehousing

- Physical separation of operational and decision support environments
- Purpose: to establish a *data repository* making operational data accessible
- Transforms operational data to relational form
- Only data needed for decision support come from the TPS
- Data are transformed and integrated into a consistent structure
- Data warehousing (or information warehousing): a solution to the data access problem
- End users perform ad hoc query, reporting analysis and visualization

Data Warehousing Benefits

- Increase in knowledge worker productivity
- Supports all decision makers' data requirements
- Provide ready access to critical data
- Insulates operation databases from ad hoc processing
- Provides high-level summary information
- Provides drill down capabilities

Yields

- Improved business knowledge
- Competitive advantage
- Enhances customer service and satisfaction
- Facilitates decision making
- Help streamline business processes

Data Warehouse Architecture and Process

- Two-tier architecture
- Three-tier architecture (Figure 4.3)

Data Warehouse Components

- Large physical database
- Logical data warehouse
- Data mart
- Decision support systems (DSS) and executive information system (EIS)

DW Suitability

For organizations where

- **Data are in different systems**
- **Information-based approach to management in use**
- **Large, diverse customer base**
- **Same data have different representations in different systems**
- **Highly technical, messy data formats**

Characteristics of Data Warehousing

1. Data organized by detailed subject with information relevant for decision support

2. Integrated data

3. Time-variant data

4. Non-volatile data

4.9 OLAP: Data Access and Mining, Querying and Analysis

Online Analytical processing (OLAP)

- DSS and EIS computing done by end-users in online systems
- Versus online transaction processing (OLTP)

OLAP Activities

- Generating queries
- Requesting ad hoc reports
- Conducting statistical analyses
- Building multimedia applications

OLAP uses the data warehouse and a *set of tools*, usually with multidimensional capabilities

- Query tools
- Spreadsheets
- Data mining tools
- Data visualization tools

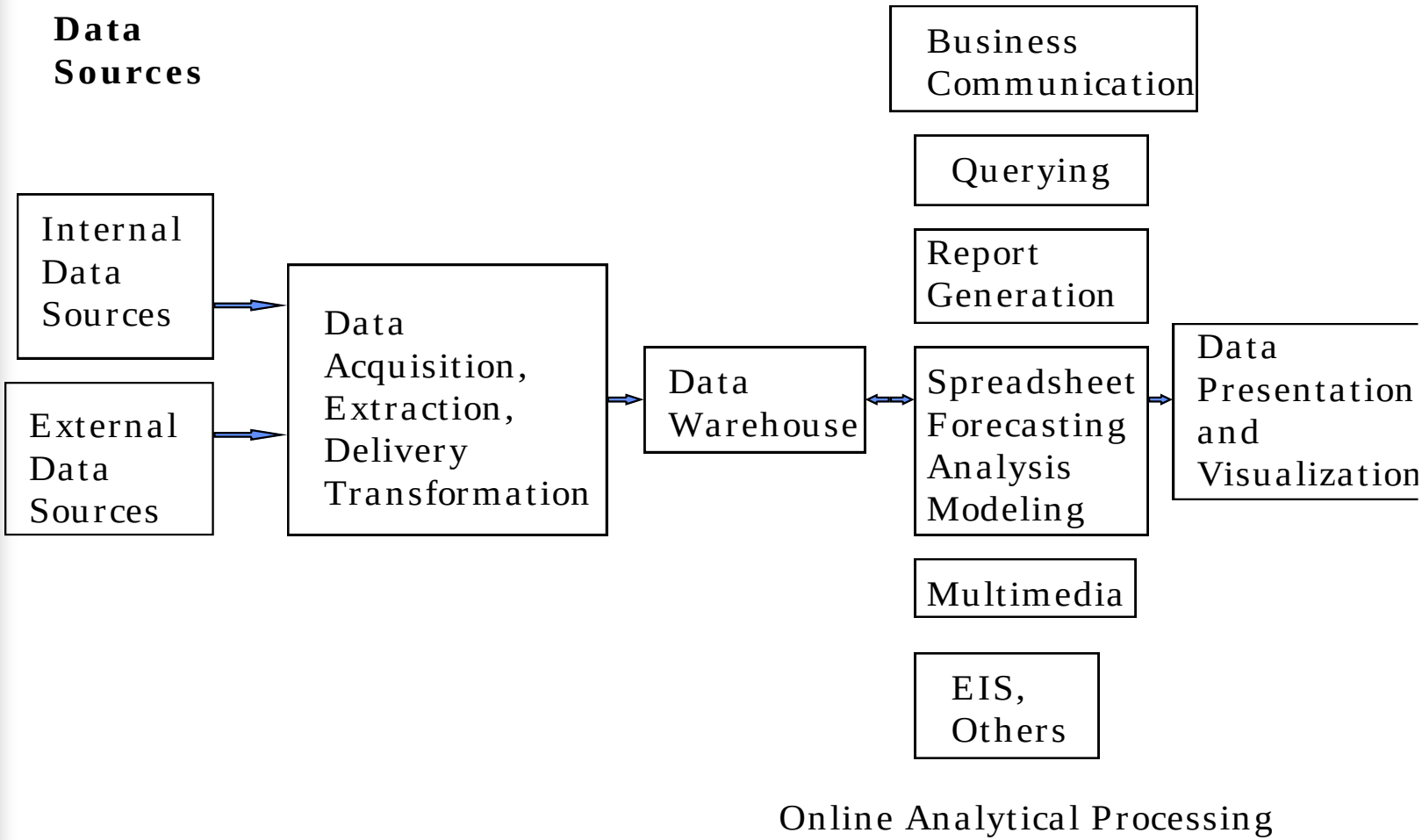

FIGURE 4.1 Data Warehousing and Online Analytical Processing (OLAP).

DSS In Focus 4.8: Database Queries

Managers may ask many questions from a computer. Here are selected representative questions that were used as benchmarks to test DSS query software by *Corporate Computing* (August 1992).

Query Group 1--Phone Number Queries

List the telephone numbers of the contacts at Sand Energy, particularly if this number is different from the company number or is missing. Otherwise list the main company phone number.

Query Group 2--Product Queries

List the number of units of each product that Sand Energy Company has ordered.

Query Group 3--Financial Queries

List the product that is part of the largest order and that is also the product most commonly ordered.

Query Group 4--Periodic Queries

Generate a cross-tabular report of the revenues per ordering customer per product in 1992.

Query Group 5--Graphing Queries

Create a pie chart that shows total dollar sales to top five customers separately, and groups total dollar sales for all other customers.

Query Group 6--Reporting Queries

Generate an order report for the latest order placed by Sand Energy Company. Include: today's date; company name; order information; line item information; total dollar amount.

(*Source:* Condensed from *Corporate Computing,* August 1992.

Using SQL for Querying

- **SQL (Structured Query Language)**
  Data language
  English-like, nonprocedural, very user friendly language
  Free format

  Example:

```
SELECT      Name, Salary
FROM        Employees
WHERE       Salary >2000
```

DSS In Focus 4.9: Sampler of SQL Statements	
Natural Language	SQL
List of all purchases of L.B. University since January of 1996, in terms of products, prices, and quantities	SELECT PRODUCTS PURCH PRICE QUANTITY FROM PURCHASE-HIST WHERE CUST-NAME EQ L.B. UNIVERSITY AND PURCH-DATE GE 01/01/96
List the price of cotton shirts, medium size, with short sleeves and white color	SELECT PRICE, AMOUNT-AVAIL FROM PRODUCT WHERE PROD-NAME EQ COTTON SHIRT AND SIZE EQ MEDIUM AND STYLE EQ SHORT SLEEVES AND COLOR EQ WHITE

Data Mining

For

- Knowledge discovery in databases
- Knowledge extraction
- Data archeology
- Data exploration
- Data pattern processing
- Data dredging
- Information harvesting

Major Data Mining Characteristics and Objectives

- Data are often buried deep
- Client/server architecture
- Sophisticated new tools--including advanced visualization tools--help to remove the information “ore”
- Massaging and synchronizing data
- Usefulness of “soft” data
- End-user minor is empowered by “data drills” and other power query tools with little or no programming skills
- Often involves finding unexpected results
- Tools are easily combined with spreadsheets etc.
- Parallel processing for data mining

Example in Figure 4.4

Data Mining Application Areas

- Marketing
- Banking:
- Retailing and sales
- Manufacturing and production
- Brokerage and securities trading
- Insurance
- Computer hardware and software
- Government and defense
- Airlines
- Health care
- Broadcasting
- Law Enforcement

4.10 Data Visualization and Multidimensionality

Data Visualization Technologies

- Digital images
- Geographic information systems
- Graphical user interfaces
- Multidimensions
- Tables and graphs
- Virtual reality
- Presentations
- Animation

DSS In Action 4.11: Data Visualization

To prevent systems from automatically identifying meaningless patterns in data, CFOs want to make sure that the processing power of a computer is always tempered with that of the insight of a human being. One way to do that is through data visualization, which uses color, form, motion, and depth to present masses of data in a comprehensible way. Andrew W. Lo, Director of the Laboratory for Financial Engineering at Massachusetts Institute of Technology's Sloan School of Management, developed a program in which a CFO can use a mouse to "fly" over a *3-D landscape representing the risk, return, and liquidity of a company's assets*. With practice, the CFO can begin to zero in on the choicest spot on the 3-D landscape--the one where the trade-off among risk, return, and liquidity is most beneficial. Says Lo: "The video-game generation just loves these 3-D tools."

So far, very few CFOs are *cruising in 3-D cyberspace*. Most still spend the bulk of their time on routine matters such as generating reports for the Securities & Exchange Commission. But that's bound to change. Says Glassco Park President Robert J. Park: "What we have in financial risk management today is like what we had in computer typesetting in 1981, before desktop publishing."

(*Source:* Condensed from: P. Coy, "Higher Math and Savvy Software are Crucial," *Business Week,* October 28, 1996.)

Multidimensionality

- 3-D + Spreadsheets
- Data can be organized the way managers like to see them, rather than the way that the system analysts do
- Different presentations of the *same data* can be arranged easily and quickly

- *Dimensions*: products, salespeople, market segments, business units, geographical locations, distribution channels, country, or industry
- *Measures*: money, sales volume, head count, inventory profit, actual versus forecasted
- *Time*: daily, weekly, monthly, quarterly, or yearly

Multidimensionality Limitations

- Extra storage requirements
- Higher cost
- Extra system resource and time consumption
- More complex interfaces and maintenance

Multidimensionality is especially popular in executive information and support systems

4.11 Intelligent Databases and Data Mining

- **Developing MSS applications requires access to databases**

  AI technologies (ES, ANN) to assist database management

- **Integration Example in Figure 4.5**
- **Link ES to large databases**
- **Example: query optimizer**
- **Natural language interfaces**

Intelligent Data Mining

- Use intelligent search to discover information within data warehouses that queries and reports cannot effectively reveal
- Find patterns in the data and infer rules from them
- Use patterns and rules to guide decision-making and forecasting
- Five common types of information that can be yielded by data mining: 1) association, 2) sequences, 3) classifications, 4) clusters, and 5) forecasting

Main Tools Used in Intelligent Data Mining

- Case-based Reasoning
- Neural Computing
- Intelligent Agents
- Other Tools
  - decision trees
  - rule induction
  - data visualization

Summary

- Data for decision making come from internal and external sources
- The database management system is one of the major components of most management support systems
- Familiarity with the latest developments is critical
- Data contain a gold mine of information if they can dig it out
- Organizations are warehousing and mining data
- Multidimensional analysis tools and new enterprise-wide system architectures are useful

Summary (cont'd.)

- Object-oriented approach to systems analysis, design, and implementation may prove useful
- New data formats for multimedia DBMS
- Internet and intranets via Web browser interfaces for DBMS access
- Built-in artificial intelligence methods in DBMS

Questions for the Opening Vignette

1. Use the Holsapple and Whinston classification system and identify the categories of the DSS applications in the case.
2. Identify the driving forces that led to the creation of the data warehouse.
3. Comment on the sources of data.
4. Identify the decisions supported by the data warehouse.
5. Read the article: Braley, D. (1996, February). "System Purchases Support Vendors' Visions." *Health Management Technology.* Vol. 17. No. 2. 13-14. Compare the evolution and developments described in the article to those in the Opening Vignette.

Exercise 4

- **The U.S. government spends millions of dollars gathering data on its population every 10 years (plus some mid-decade corrections). Census data are critical in determining the representation of each state in the House of Representatives and the number of Electoral College votes to which each state is entitled for Presidential elections. More importantly, census data provide information about U.S. markets. The demographics indicate family and gender make up, incomes, education level, etc. for the states, metropolitan statistical areas (MSA), and counties. Such data are available from various sources including books, disk, CD-ROM and the World Wide Web (see Internet Exercise 5). In this exercise, we take a real-world view of external, but readily available data.**

1. Find an electronic source of standard census data files for the states and MSAs.
2. Access the data and examine the file structures. Do the contents and organization of each make sense? Why or why not? If not, suggest improvements.
3. Load the state P1 data population table into a spreadsheet file (Excel if possible) and into a database file (ACCESS if possible). How difficult was this? How could this have been made easier? Don't forget to delete the comments and U.S. totals (if present) at the top, for later use. Note that Washington, DC is listed as well. Print the table.

4. Using the state P1 population data, sort the data, based on population size. What are the five most populated states, and the five least populated states? Which five states have the largest and smallest population densities? Which state has the most males and which state has the most females? Which three states have the most people living on farms, and which state has the least lonely people? Which file type (spreadsheet or database) did you use and why? What features made it easy to do these analyses?

5. Load the State Basic Table P6 (Household Income) into a spreadsheet or database file. Which five states have the most people earning $100,000 or more per year? Which five states have the highest percentages of people earning $100,000 or more per year? Combining these data with data from Table P1, which five states have the most people per square mile earning $100,000 or more per year? Which file type (spreadsheet or database) did you use and why? What features made it easy to do these analyses?

6. Data warehousing and data mining are used to combine data and identify patterns. Using data (load and save them into spreadsheet or database files) from files:

a) P1 Population
b) P3 Persons by Age
c) P4 Households by Size
d) P6 Household Income
e) P8 Other Income Measures
f) P9 Level of Education.

- **Synthesize these tables into a usable set and determine if there are any relationships at the state level between:**

  Population per square mile and education
  Income and age
  Household size and education

  Can you think of any other relationships to explore? Do so. What made this task difficult or easy? Explain.

7. Examine the MSA data tables and see if any of the relationships found for the state data above hold.

8. How does your MSA (or one closest to where you live) compare to your state's census profile and that of the entire United States? How did you determine this?

Group Exercise

- **One of the most difficult tasks in any large city is traffic law enforcement. According to *PCWeek*, Nov. 13, 1993, p. 63, a solution to the problem can be found in a client/server-based data warehousing system. Read the article and then visit your local traffic enforcement agency.**

  a) Review the current information system.
  b) Identify problems in the existing system.
  c) Explain how a system like the one described in the *PCWeek* story can help your local agency.

Case Application 4.1: Data Warehousing at the Canadian Imperial Bank of Commerce

- 2nd largest bank in Canada
- One of the top 10 banks in North America
- Decision support applications supported by a data warehouse
- Data warehouse provides diverse decision-making support
- Analyses supported include customer traffic patterns at branches
- Data warehouse evolved over time
- The secret is to hold the data at the event level and summarize them to the level of granularity appropriate for specific queries
- Statistical modeling and consulting
- Supports EIS

Benefits of the Data Warehouse Structure

- Data integrity
- Consistency across time lines
- High efficiency
- Low operating costs
- Can store data at different levels of summarization
- Can give customers quick turnaround

Appendix W4-A: Object-oriented Systems Analysis, Design and Programming

W4-A.1 Introduction to the Object-Oriented Approach

Objects are created and manipulated, rather than 'items' in programs

Objects have

- Certain features or attributes
- Exhibit certain behaviors
- Interact

- **Objects can be grouped and classified, like real-world objects**
- **Specific objects (a specific person) have certain attributes by being in a class (employees, citizens, customers, etc.)**
- **An object knows what it is and what it can do**

W4-A.2 Object Think

- The system analyst focuses on the user requirements that lead directly to the definition and subsequent development of objects

  Objects have characteristics that they exhibit, and inherit characteristics directly from their class, and from their "parents"

  Example: University library
- Class of objects called "books"
- Class of objects called "borrowers
  See Figure 4-A.1

W4-A.3 Important Object-Oriented Approach Terminology

Object: a thing - a specific instance
An object knows what it is and what it can do

Class: a type of thing, and all specific things that fit the general definition of the class belong to the class
Like a data entity type when modeling data
A class is the general category and an object is a specific instance

Attributes of a Class: The attributes that all of the objects in the class share define a class of objects
The attribute values are part of what an object knows when using the object think approach

Association Relationships:

Objects may be related to other objects

These are similar to relationships in a data model. A relationship is an association based on the context in which we view objects, e.g., a natural association

These relationships have names, can be optional or mandatory, and have cardinality

Whole-part Relationships:

Stronger than association relationships

Strong relationships between an object and other objects that are its parts

Methods or Services of a Class:

- A method is something the object knows how to do
- Service is something that the object knows how to do for a requester

- *Standard services:* all objects know how to do
- *Complex services:* custom designed for the class of objects

Encapsulation or Information Hiding:

- *Encapsulation* means packaging several items together into one unit
- Packaging both the attributes and services of the class together so that the object knows things (attributes) and how to do things (services).
- We *hide* the internal structure of an object from the environment

Message Sending:

- End users can send messages to objects to perform a service
- Objects can send messages to other objects Messages may also be triggered temporally

Polymorphism (Multiple forms):

- **Different kinds of related items**

Inheritance, Classification Hierarchies and Reuse:

- **Classification hierarchies allow classes of objects to inherit attributes from larger classes**
- **Allows for object reuse**
- **Pre-defined classes of interface objects**

W4-A.4 The Object-Oriented System Development Cycle

1. Object-Oriented Analysis

2. Object-Oriented Design

3. Object-Oriented Implementation

Object-Oriented Analysis

- Define system requirements through scenarios or use cases
- Then, build an object model with the capability to satisfy the requirements
- Output: requirements model

Object-Oriented Design

- The requirements model created in the analysis phase is enhanced in the design phase.
- Sometimes more attributes and services are added
- Interface objects are added

Object-Oriented Implementation

- Usable system is developed
- Use object-oriented programming languages
- If needed, provide links to a separate database management system

Object-Oriented CASE Tools

- New capabilities are being developed

W4-A.5 Object-Oriented Programming Languages

- **Pure**
  - **Smalltalk**
- **Hybrid:**
  - **C++**
- **Also:**
  - **Object-oriented Cobol**
  - **Ada**
  - **Objective C**
  - **Object Pascal**
  - **Actor**
  - **Eiffel**
  - **and more**

W4.A-6 Object Oriented Database Management Systems

The database system must

1. **Support complex objects**
2. **Support object identity**
3. **Allow objects to be encapsulated**
4. **Support types or classes**
5. **Support inheritance**
6. **Avoid premature binding**
7. **Be computationally complete**

8. Be extensible
9. Be able to remember data locations
10. Be able to manage large databases
11. Accept concurrent users
12. Be able to recover from hardware/software failures
13. Support data query in a simple way

Norman [1996]

Strengths and Weaknesses of an Object-Oriented Database

Strengths

1. Data Modeling
2. Nonhomogeneous data
3. Variable length and long strings
4. Complex objects
5. Version control
6. Schema evolution
7. Equivalent objects
8. Long transactions
9. User Benefits

Weaknesses

1 .New problem solving approach
2. Lack of a common data model with a strong theoretical foundation
3. Limited success stories

Norman [1996]

Companies

- Versant Object Technology Corp. (Menlo Park, CA - Versant ODBMS)
- KE Software Inc. (Vancouver, BC - http://www.kesoftware.com/ - try the demo)
- O_2 Technology (Palo Alto, CA - http://www.o2tech.fr/ - try the demo)
- Object Design Inc. (Burlington, MA)
- Hewlett-Packard Co. (OpenODB)
- Itasca Systems Inc. (Itasca Distributed Management System)

- Object Design Inc. (ObjectStore)
- Objectivity Inc. (Objectivity/DB)
- Ontos Inc. (Ontos DB)
- Servio Corp. (Gemstone)
- UniSQL Inc. (UniSQL/X, UniSQL/M)

W4-A.7 Commercial Applications of the Object-Oriented Approach

- From enterprise information systems, maintenance management and financial applications to Geographical Information Systems
- EDS's Maintenance Management System (MMS)
- Time Warner Communications: a variety of business applications
- Sprint Corp. developed an object-oriented order-entry sales system to speed the providing of phone service

W4-A.8 Summary and Conclusions

- Many demonstrated successes
- But a paradigm shift is required
- The entire organization must adopt object-think
- Revolutionary change
- Transition may be bumpy

TABLE W4.1 The Benefits and Potential Problems of the Client / Server Architecture.

Feature	Benefit	Potential Problems
Networked webs of small, powerful computers	If one machine goes down, your business machines stay up. The appropriate task may be run on the appropriate computer	No one machine may be capable of storing the entire database No one machine may be capable of performing necessary computational tasks Parts don't always work together. There are several possible culprits when something goes wrong Designing the division of work between client and server may be complicated
Computer arrays with thousands of MIPS; clients' aggregate MIPS beyond calculation	The system provides the power to get things done without monopolizing resources. End-users are empowered to work locally	Coordination of efforts and communication contention may occur
Some workstations are as powerful as mainframes, but cost 90% less	By giving you more power for less money, the system offers you the flexibility to make other purchases or to increase your profits	You locate or build support tools yourself The software developed for the Mac or Windows is different from that for mainframes The computational power may be underutilized
Open systems	You can pick and choose hardware, software, and services from various vendors	Too many options and / or incompatible systems may be difficult to manage and maintain

TABLE W4.1 The Benefits and Potential Problems of the Client / Server Architecture (cont'd).

Feature	Benefit	Potential Problems
Systems grow easily and are infinitely expandable	It's easy to modernize your system as your needs change. Expanded capacity may be added incrementally	Continual upgrades may cause incompatible software problems Older machines may not run newer software
Individual client operating environments	You can mix and match computer platforms to suit the needs of individual departments and users	Managing and maintaining a variety of small systems can be difficult

Source: Based in part on *Byte*, June 1993, p. 100.