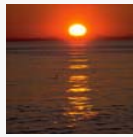
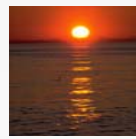
Chapter 8: Application Design and Development

Database System Concepts



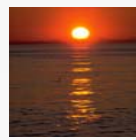
Chapter 8: Application Design and Development

- User Interfaces and Tools
- Web Interfaces to Databases
- Web Fundamentals
- Servlets and JSP
- Building Large Web Applications
- Triggers
- Authorization in SQL
- Application Security



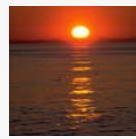
User Interfaces and Tools

- Most database users do *not* use a query language like SQL.
  - Forms
  - Graphical user interfaces
  - Report generators
  - Data analysis tools (see Chapter 18)
- Many interfaces are Web-based
- Back-end (Web server) uses such technologies as
  - Java servlets
  - Java Server Pages (JSP)
  - Active Server Pages (ASP)



The World Wide Web

- The Web is a distributed information system based on hypertext.
- Most Web documents are hypertext documents formatted via the HyperText Markup Language (HTML)
- HTML documents contain
  - text along with font specifications, and other formatting instructions
  - hypertext links to other documents, which can be associated with regions of the text.
  - forms, enabling users to enter data which can then be sent back to the Web server

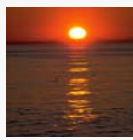


A formatted report

Acme Supply Company, Inc.
Quarterly Sales Report

Period: Jan. 1 to March 31, 2005

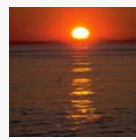
Region	Category	Sales	Subtotal
North	Computer Hardware	1,000,000	
	Computer Software	500,000	
	All categories		1,500,000
South	Computer Hardware	200,000	
	Computer Software	400,000	
	All categories		600,000
		Total Sales	2,100,000



Web Interfaces to Databases

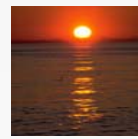
Why interface databases to the Web?

1. Web browsers have become the de-facto standard user interface to databases
   - Enable large numbers of users to access databases from anywhere
   - Avoid the need for downloading/installing specialized code, while providing a good graphical user interface
   - Examples: banks, airline and rental car reservations, university course registration and grading, an so on.



Web Interfaces to Database (Cont.)

2. Dynamic generation of documents
   - Limitations of static HTML documents
     - Cannot customize fixed Web documents for individual users.
     - Problematic to update Web documents, especially if multiple Web documents replicate data.
   - Solution: Generate Web documents dynamically from data stored in a database.
     - Can tailor the display based on user information stored in the database.
       - E.g. tailored ads, tailored weather and local news, …
     - Displayed information is up-to-date, unlike the static Web pages
       - E.g. stock market information, ..

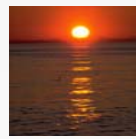


Uniform Resources Locators

- In the Web, functionality of pointers is provided by Uniform Resource Locators (URLs).
- URL example:

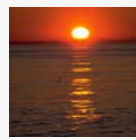
  http://www.bell-labs.com/topics/book/db-book

  - The first part indicates how the document is to be accessed
    - "http" indicates that the document is to be accessed using the Hyper Text Transfer Protocol.
  - The second part gives the unique name of a machine on the Internet.
  - The rest of the URL identifies the document within the machine.
- The local identification can be:
  - The path name of a file on the machine, or
  - An identifier (path name) of a program, plus arguments to be passed to the program
    - E.g. http://www.google.com/search?q=silberschatz



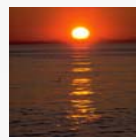
HTML and HTTP

- HTML provides formatting, hypertext link, and image display features.
- HTML also provides input features
  - Select from a set of options
    - Pop-up menus, radio buttons, check lists
  - Enter values
    - Text boxes
  - Filled in input sent back to the server, to be acted upon by an executable at the server
- HyperText Transfer Protocol (HTTP) used for communication with the Web server

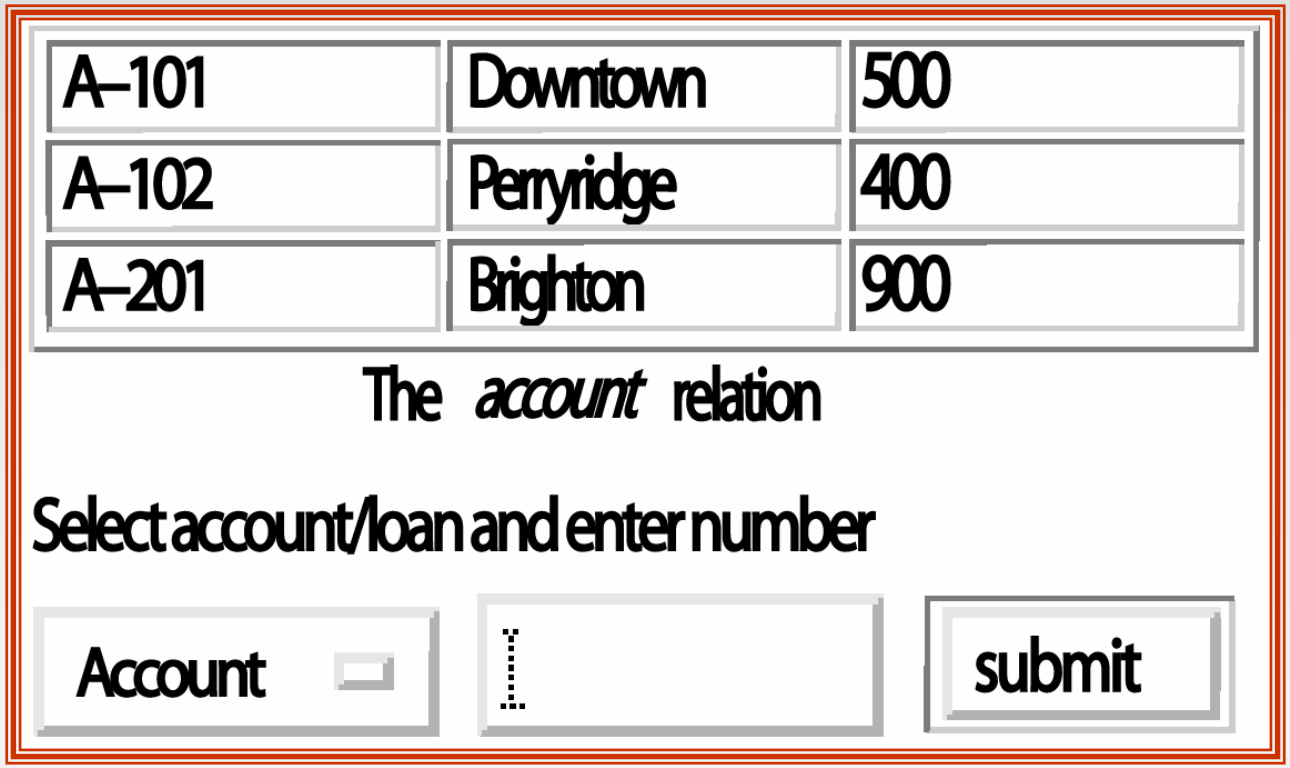


Sample HTML Source Text

```
<html> <body>
<table border cols = 3>
        <tr> <td> A-101 </td> <td> Downtown </td> <td> 500 </td> </tr>
        …
</table>
<center> The <i>account</i> relation </center>

<form action="BankQuery" method=get>
  Select account/loan and enter number <br>
  <select name="type">
     <option value="account" selected> Account
     <option> value="Loan">                Loan
  </select>
  <input type=text size=5 name="number">
  <input type=submit value="submit">
</form>
</body> </html>
```

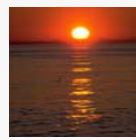


Display of Sample HTML Source



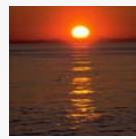
Client Side Scripting and Applets

- Browsers can fetch certain scripts (client-side scripts) or programs along with documents, and execute them in "safe mode" at the client site
  - Javascript
  - Macromedia Flash and Shockwave for animation/games
  - VRML
  - Applets
- Client-side scripts/programs allow documents to be active
  - E.g., animation by executing programs at the local site
  - E.g. ensure that values entered by users satisfy some correctness checks
  - Permit flexible interaction with the user.
    - Executing programs at the client site speeds up interaction by avoiding many round trips to server



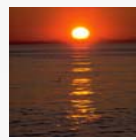
Client Side Scripting and Security

- Security mechanisms needed to ensure that malicious scripts do not cause damage to the client machine
  - Easy for limited capability scripting languages, harder for general purpose programming languages like Java
- E.g. Java's security system ensures that the Java applet code does not make any system calls directly
  - Disallows dangerous actions such as file writes
  - Notifies the user about potentially dangerous actions, and allows the option to abort the program or to continue execution.

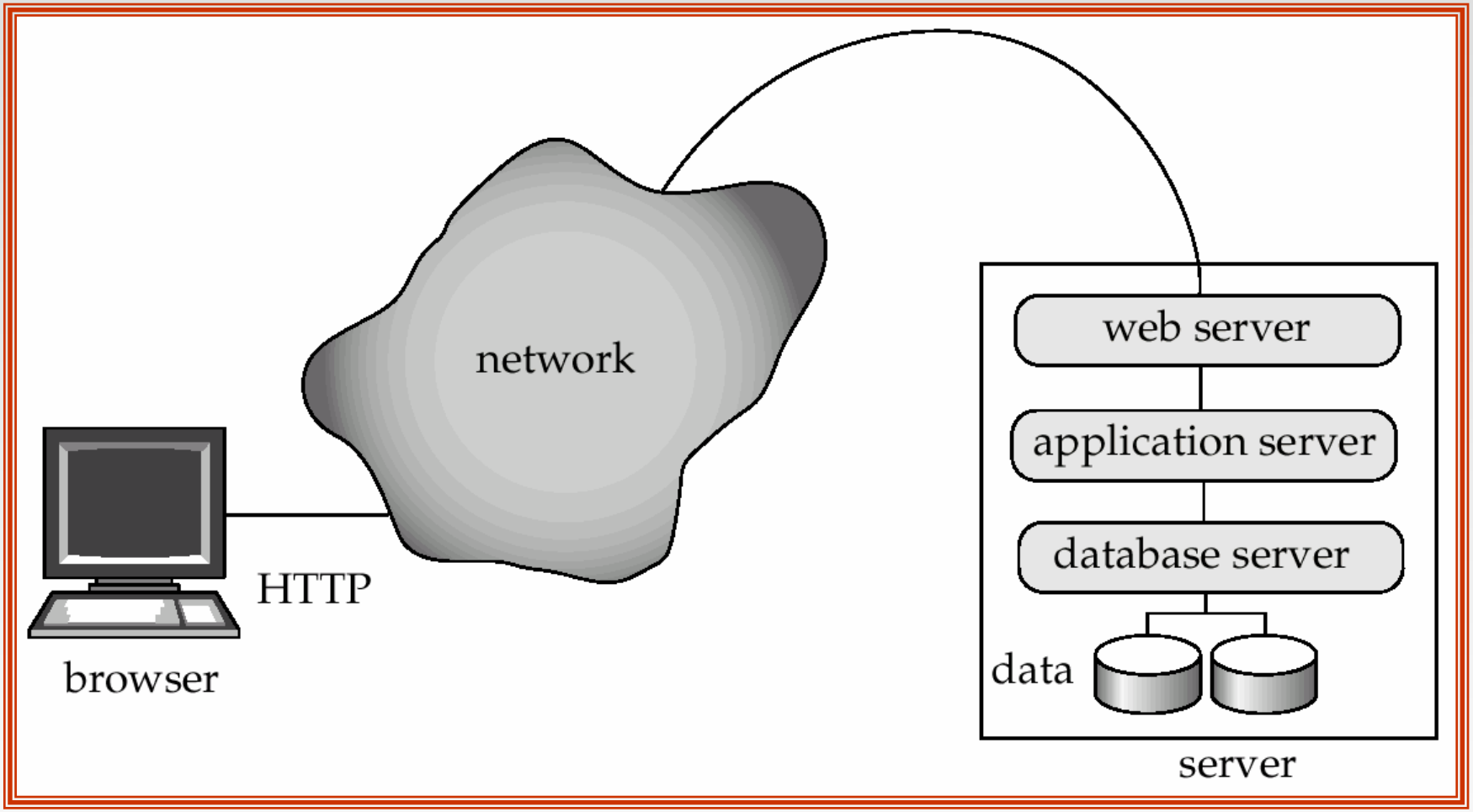


Web Servers

- A Web server can easily serve as a front end to a variety of information services.
- The document name in a URL may identify an executable program, that, when run, generates a HTML document.
  - When a HTTP server receives a request for such a document, it executes the program, and sends back the HTML document that is generated.
  - The Web client can pass extra arguments with the name of the document.
- To install a new service on the Web, one simply needs to create and install an executable that provides that service.
  - The Web browser provides a graphical user interface to the information service.
- Common Gateway Interface (CGI): a standard interface between web and application server

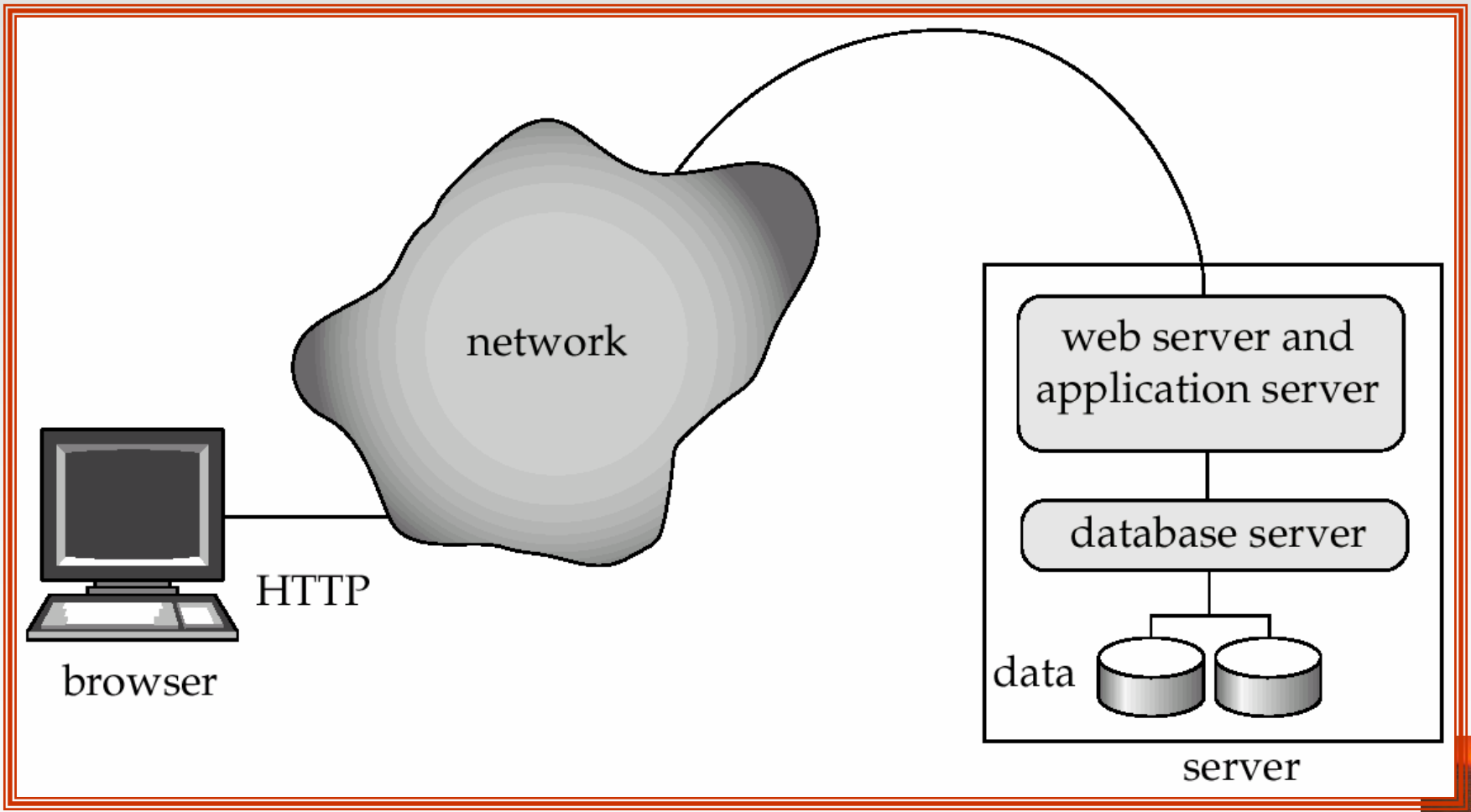


Three-Tier Web Architecture



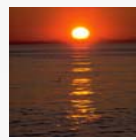
Two-Tier Web Architecture

- Multiple levels of indirection have overheads
  - Alternative: two-tier architecture



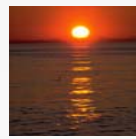
HTTP and Sessions

- The HTTP protocol is connectionless
  - That is, once the server replies to a request, the server closes the connection with the client, and forgets all about the request
  - In contrast, Unix logins, and JDBC/ODBC connections stay connected until the client disconnects
    - retaining user authentication and other information
  - Motivation: reduces load on server
    - operating systems have tight limits on number of open connections on a machine
- Information services need session information
  - E.g. user authentication should be done only once per session
- Solution: use a cookie



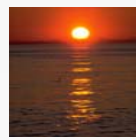
Sessions and Cookies

- A cookie is a small piece of text containing identifying information
  - Sent by server to browser on first interaction
  - Sent by browser to the server that created the cookie on further interactions
    - part of the HTTP protocol
  - Server saves information about cookies it issued, and can use it when serving a request
    - E.g., authentication information, and user preferences
- Cookies can be stored permanently or for a limited time



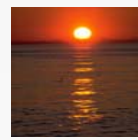
Servlets

- Java Servlet specification defines an API for communication between the Web server and application program
  - E.g. methods to get parameter values and to send HTML text back to client
- Application program (also called a servlet) is loaded into the Web server
  - Two-tier model
  - Each request spawns a new thread in the Web server
    - thread is closed once the request is serviced
- Servlet API provides a getSession() method
  - Sets a cookie on first interaction with browser, and uses it to identify session on further interactions
  - Provides methods to store and look-up per-session information
    - E.g. user name, preferences, ..



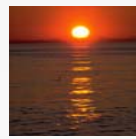
Example Servlet Code

```
Public class BankQuery(Servlet extends HttpServlet {
    public void doGet(HttpServletRequest request, HttpServletResponse result)
            throws ServletException, IOException {

            String type = request.getParameter("type");
            String number = request.getParameter("number");

              …code to find the loan amount/account balance …
              …using JDBC to communicate with the database..
              …we assume the value is stored in the variable balance

            result.setContentType("text/html");
            PrintWriter out = result.getWriter( );
            out.println("<HEAD><TITLE>Query Result</TITLE></HEAD>");
            out.println("<BODY>");
            out.println("Balance on " + type + number + "=" + balance);
            out.println("</BODY>");
            out.close ( );
    }
}
```



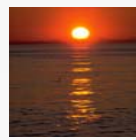
Server-Side Scripting

- Server-side scripting simplifies the task of connecting a database to the Web
  - Define a HTML document with embedded executable code/SQL queries.
  - Input values from HTML forms can be used directly in the embedded code/SQL queries.
  - When the document is requested, the Web server executes the embedded code/SQL queries to generate the actual HTML document.
- Numerous server-side scripting languages
  - JSP, Server-side Javascript, ColdFusion Markup Language (cfml), PHP, Jscript
  - General purpose scripting languages: VBScript, Perl, Python



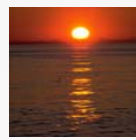
Improving Web Server Performance

- Performance is an issue for popular Web sites
  - May be accessed by millions of users every day, thousands of requests per second at peak time
- Caching techniques used to reduce cost of serving pages by exploiting commonalities between requests
  - At the server site:
    - Caching of JDBC connections between servlet requests
    - Caching results of database queries
      - Cached results must be updated if underlying database changes
    - Caching of generated HTML
  - At the client's network
    - Caching of pages by Web proxy



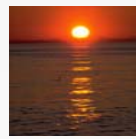
Triggers

- A **trigger** is a statement that is executed automatically by the system as a side effect of a modification to the database.
- To design a trigger mechanism, we must:
  - Specify the conditions under which the trigger is to be executed.
  - Specify the actions to be taken when the trigger executes.
- Triggers introduced to SQL standard in SQL:1999, but supported even earlier using non-standard syntax by most databases.



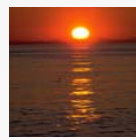
Trigger Example

- Suppose that instead of allowing negative account balances, the bank deals with overdrafts by
  - setting the account balance to zero
  - creating a loan in the amount of the overdraft
  - giving this loan a loan number identical to the account number of the overdrawn account
- The condition for executing the trigger is an update to the *account* relation that results in a negative *balance* value.



Trigger Example in SQL:1999

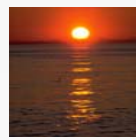
```
create trigger overdraft-trigger after update on account
referencing new row as nrow
for each row
when nrow.balance < 0
begin atomic
        insert into borrower
           (select customer-name, account-number
            from depositor
            where nrow.account-number =
                        depositor.account-number);
        insert into loan values
           (n.row.account-number, nrow.branch-name,
                                                – nrow.balance);
        update account set balance = 0
         where account.account-number = nrow.account-number
end
```



Triggering Events and Actions in SQL

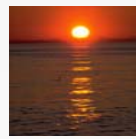
- Triggering event can be **insert**, **delete** or **update**
- Triggers on update can be restricted to specific attributes
  - **E.g. create trigger** *overdraft-trigger* **after update of** *balance* **on** *account*
- Values of attributes before and after an update can be referenced
  - **referencing old row as** : for deletes and updates
  - **referencing new row as :** for inserts and updates
- Triggers can be activated before an event, which can serve as extra constraints. E.g. convert blanks to null.

```
create trigger setnull-trigger before update on r
referencing new row as nrow
for each row
    when nrow.phone-number = ' '
    set nrow.phone-number = null
```



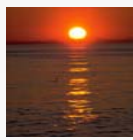
Statement Level Triggers

- Instead of executing a separate action for each affected row, a single action can be executed for all rows affected by a transaction
  - Use **for each statement** instead of **for each row**
  - Use **referencing old table** or **referencing new table** to refer to temporary tables (called ***transition tables***) containing the affected rows
  - Can be more efficient when dealing with SQL statements that update a large number of rows



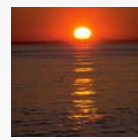
External World Actions

- We sometimes require external world actions to be triggered on a database update
  - E.g. re-ordering an item whose quantity in a warehouse has become small, or turning on an alarm light,
- Triggers cannot be used to directly implement external-world actions, BUT
  - Triggers can be used to record actions-to-be-taken in a separate table
  - Have an external process that repeatedly scans the table, carries out external-world actions and deletes action from table
- E.g. Suppose a warehouse has the following tables
  - *inventory* (*item, level*)*:* How much of each item is in the warehouse
  - *minlevel* (*item, level*) *:* What is the minimum desired level of each item
  - *reorder* (*item, amount*)*:* What quantity should we re-order at a time
  - *orders* (*item, amount*) *:* Orders to be placed (read by external process)



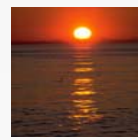
External World Actions (Cont.)

```
create trigger reorder-trigger after update of amount on inventory
referencing old row as orow, new row as nrow
for each row
        when nrow.level < = (select level
                                    from minlevel
                                    where minlevel.item = orow.item)
                and orow.level > (select level
                                        from minlevel
                                       where minlevel.item = orow.item)
  begin
          insert into orders
                (select item, amount
                  from reorder
                  where reorder.item = orow.item)
  end
```



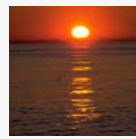
Triggers in MS-SQLServer Syntax

```
create trigger overdraft-trigger on account
 for update
 as
 if  inserted.balance < 0
 begin
    insert into borrower
       (select customer-name,account-number
        from depositor, inserted
        where inserted.account-number =
                          depositor.account-number)
    insert into loan values
       (inserted.account-number, inserted.branch-name,
                          – inserted.balance)
    update account set balance = 0
      from account, inserted
      where account.account-number = inserted.account-number
 end
```



When Not To Use Triggers

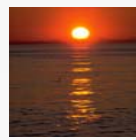
- Triggers were used earlier for tasks such as
  - maintaining summary data (e.g. total salary of each department)
  - Replicating databases by recording changes to special relations (called **change** or **delta** relations) and having a separate process that applies the changes over to a replica
- There are better ways of doing these now:
  - Databases today provide built in materialized view facilities to maintain summary data
  - Databases provide built-in support for replication
- Encapsulation facilities can be used instead of triggers in many cases
  - Define methods to update fields
  - Carry out actions as part of the update methods instead of through a trigger



Authorization in SQL (see also Section 4.3)

Forms of authorization on parts of the database:

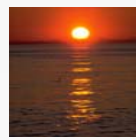
- **Read authorization** - allows reading, but not modification of data.
- **Insert authorization** - allows insertion of new data, but not modification of existing data.
- **Update authorization** - allows modification, but not deletion of data.
- **Delete authorization** - allows deletion of data



Authorization (Cont.)

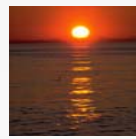
Forms of authorization to modify the database schema:

- **Index authorization** - allows creation and deletion of indices.
- **Resources authorization** - allows creation of new relations.
- **Alteration authorization** - allows addition or deletion of attributes in a relation.
- **Drop authorization** - allows deletion of relations.



Authorization and Views

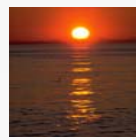
- Users can be given authorization on views, without being given any authorization on the relations used in the view definition
- Ability of views to hide data serves both to simplify usage of the system and to enhance security by allowing users access only to data they need for their job
- A combination or relational-level security and view-level security can be used to limit a user's access to precisely the data that user needs.



View Example

- Suppose a bank clerk needs to know the names of the customers of each branch, but is not authorized to see specific loan information.
  - Approach: Deny direct access to the *loan* relation, but grant access to the view *cust-loan*, which consists only of the names of customers and the branches at which they have a loan.
  - The *cust-loan* view is defined in SQL as follows:

```
create view cust-loan as
    select branchname, customer-name
    from   borrower, loan
    where borrower.loan-number = loan.loan-number
```



View Example (Cont.)

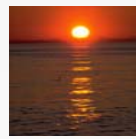
- The clerk is authorized to see the result of the query:

  select *
  from *cust-loan*

- When the query processor translates the result into a query on the actual relations in the database, we obtain a query on *borrower* and *loan*.
- Authorization must be checked on the clerk's query before query processing replaces a view by the definition of the view.

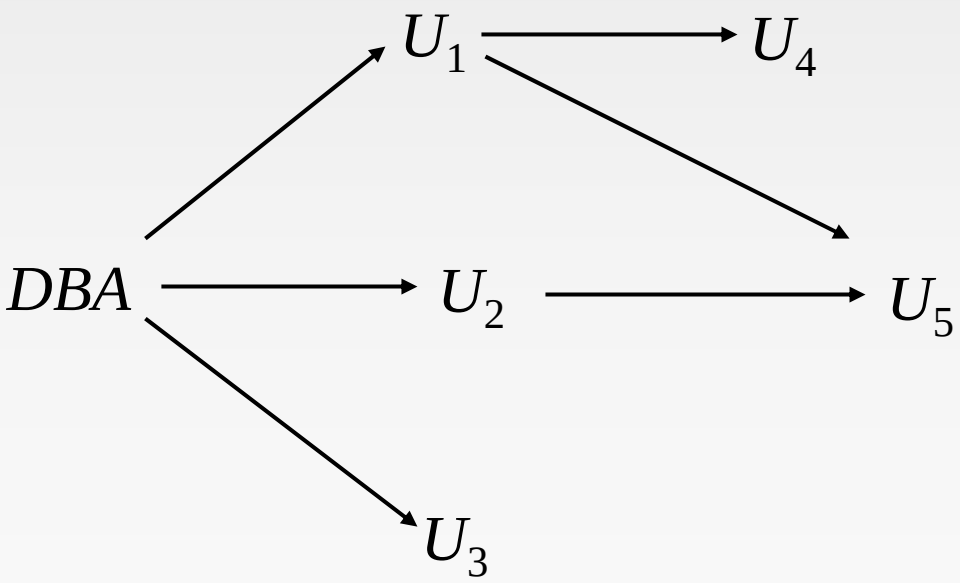
Authorization on Views

- Creation of view does not require **resources** authorization since no real relation is being created
- The creator of a view gets only those privileges that provide no additional authorization beyond that he already had.
- E.g. if creator of view *cust-loan* had only **read** authorization on *borrower* and *loan*, he gets only **read** authorization on *cust-loan*



Granting of Privileges

- The passage of authorization from one user to another may be represented by an authorization graph.
- The nodes of this graph are the users.
- The root of the graph is the database administrator.
- Consider graph for update authorization on loan.
- An edge $U_i \rightarrow U_j$ indicates that user U_i has granted update authorization on loan to U_j.



Authorization Grant Graph

- *Requirement*: All edges in an authorization graph must be part of some path originating with the database administrator
- If DBA revokes grant from U_1:
  - Grant must be revoked from U_4 since U_1 no longer has authorization
  - Grant must not be revoked from U_5 since U_5 has another authorization path from DBA through U_2
- Must prevent cycles of grants with no path from the root:
  - DBA grants authorization to U_7
  - U_7 grants authorization to U_8
  - U_8 grants authorization to U_7
  - DBA revokes authorization from U_7
- Must revoke grant U_7 to U_8 and from U_8 to U_7 since there is no path from DBA to U_7 or to U_8 anymore.

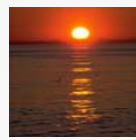
Security Specification in SQL

- The grant statement is used to confer authorization

  grant <privilege list>

  on <relation name or view name> to <user list>

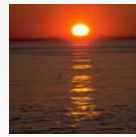
- <user list> is:
  - a user-id
  - *public*, which allows all valid users the privilege granted
  - A role (more on this later)
- Granting a privilege on a view does not imply granting any privileges on the underlying relations.
- The grantor of the privilege must already hold the privilege on the specified item (or be the database administrator).



Privileges in SQL

- **select:** allows read access to relation,or the ability to query using the view
  - Example: grant users U_1, U_2, and U_3 **select** authorization on the *branch* relation:

    grant select on *branch* **to** U_1, U_2, U_3
- **insert**: the ability to insert tuples
- **update**: the ability to update using the SQL update statement
- **delete**: the ability to delete tuples.
- **references**: ability to declare foreign keys when creating relations.
- **usage**: In SQL-92; authorizes a user to use a specified domain
- **all privileges**: used as a short form for all the allowable privileges



Privilege To Grant Privileges

- **with grant option**: allows a user who is granted a privilege to pass the privilege on to other users.
  - Example:

    grant select on *branch* **to** U_1 **with grant option**

    gives U_1 the **select** privileges on branch and allows U_1 to grant this

    privilege to others

Roles

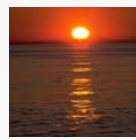
- Roles permit common privileges for a class of users can be specified just once by creating a corresponding “role”
- Privileges can be granted to or revoked from roles, just like user
- Roles can be assigned to users, and even to other roles
- SQL:1999 supports roles

create role *teller*
create role *manager*

grant select on *branch* **to** *teller*
grant update (*balance***) on** *account* **to** *teller*
grant all privileges on *account* **to** *manager*

grant *teller* **to** *manager*

grant *teller* **to** *alice, bob*
grant *manager* **to** *avi*



Revoking Authorization in SQL

- The **revoke** statement is used to revoke authorization.

  revoke<privilege list>

  on <relation name or view name> **from** <user list>
  [**restrict**|**cascade**]

- Example:

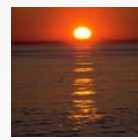
  revoke select on *branch* **from** U_1, U_2, U_3 **cascade**

- Revocation of a privilege from a user may cause other users also to lose that privilege; referred to as cascading of the **revoke**.

- We can prevent cascading by specifying **restrict**:

  revoke select on *branch* **from** U_1, U_2, U_3 **restrict**

  With **restrict**, the **revoke** command fails if cascading revokes are required.

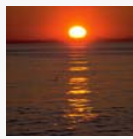


Revoking Authorization in SQL (Cont.)

- <privilege-list> may be **all to** revoke all privileges the revokee may hold.
- If <revokee-list> includes **public** all users lose the privilege except those granted it explicitly.
- If the same privilege was granted twice to the same user by different grantees, the user may retain the privilege after the revocation.
- All privileges that depend on the privilege being revoked are also revoked.

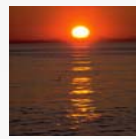
Limitations of SQL Authorization

- SQL does not support authorization at a tuple level
  - E.g. we cannot restrict students to see only (the tuples storing) their own grades
- With the growth in Web access to databases, database accesses come primarily from application servers.
  - End users don't have database user ids, they are all mapped to the same database user id
- All end-users of an application (such as a web application) may be mapped to a single database user
- The task of authorization in above cases falls on the application program, with no support from SQL
  - Benefit: fine grained authorizations, such as to individual tuples, can be implemented by the application.
  - Drawback: Authorization must be done in application code, and may be dispersed all over an application
  - Checking for absence of authorization loopholes becomes very difficult since it requires reading large amounts of application code



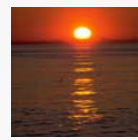
Audit Trails

- An audit trail is a log of all changes (inserts/deletes/updates) to the database along with information such as which user performed the change, and when the change was performed.
- Used to track erroneous/fraudulent updates.
- Can be implemented using triggers, but many database systems provide direct support.



Application Security

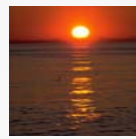
- Data may be *encrypted* when database authorization provisions do not offer sufficient protection.
- Properties of good encryption technique:
  - Relatively simple for authorized users to encrypt and decrypt data.
  - Encryption scheme depends not on the secrecy of the algorithm but on the secrecy of a parameter of the algorithm called the encryption key.
  - Extremely difficult for an intruder to determine the encryption key.



Encryption (Cont.)

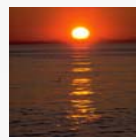
- *Data Encryption Standard* (DES) substitutes characters and rearranges their order on the basis of an encryption key which is provided to authorized users via a secure mechanism. Scheme is no more secure than the key transmission mechanism since the key has to be shared.
- Advanced Encryption Standard (AES) is a new standard replacing DES, and is based on the Rijndael algorithm, but is also dependent on shared secret keys
- *Public-key encryption* is based on each user having two keys:
  - *public key* – publicly published key used to encrypt data, but cannot be used to decrypt data
  - *private key* -- key known only to individual user, and used to decrypt data. Need not be transmitted to the site doing encryption.

  Encryption scheme is such that it is impossible or extremely hard to decrypt data given only the public key.
- The RSA public-key encryption scheme is based on the hardness of factoring a very large number (100's of digits) into its prime components.



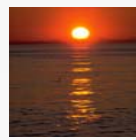
Authentication

- Password based authentication is widely used, but is susceptible to sniffing on a network
- **Challenge-response** systems avoid transmission of passwords
  - DB sends a (randomly generated) challenge string to user
  - User encrypts string and returns result.
  - DB verifies identity by decrypting result
  - Can use public-key encryption system by DB sending a message encrypted using user's public key, and user decrypting and sending the message back
- **Digital signatures** are used to verify authenticity of data
  - E.g. use private key (in reverse) to encrypt data, and anyone can verify authenticity by using public key (in reverse) to decrypt data. Only holder of private key could have created the encrypted data.
  - Digital signatures also help ensure **nonrepudiation:** sender cannot later claim to have not created the data



Digital Certificates

- **Digital certificates** are used to verify authenticity of public keys.
- Problem: when you communicate with a web site, how do you know if you are talking with the genuine web site or an imposter?
  - Solution: use the public key of the web site
  - Problem: how to verify if the public key itself is genuine?
- Solution:
  - Every client (e.g. browser) has public keys of a few root-level **certification authorities**
  - A site can get its name/URL and public key signed by a certification authority: signed document is called a **certificate**
  - Client can use public key of certification authority to verify certificate
  - Multiple levels of certification authorities can exist. Each certification authority
    - presents its own public-key certificate signed by a higher level authority, and
    - Uses its private key to sign the certificate of other web sites/authorities



End of Chapter