Using Relationship Patterns to Model Superimposed Information

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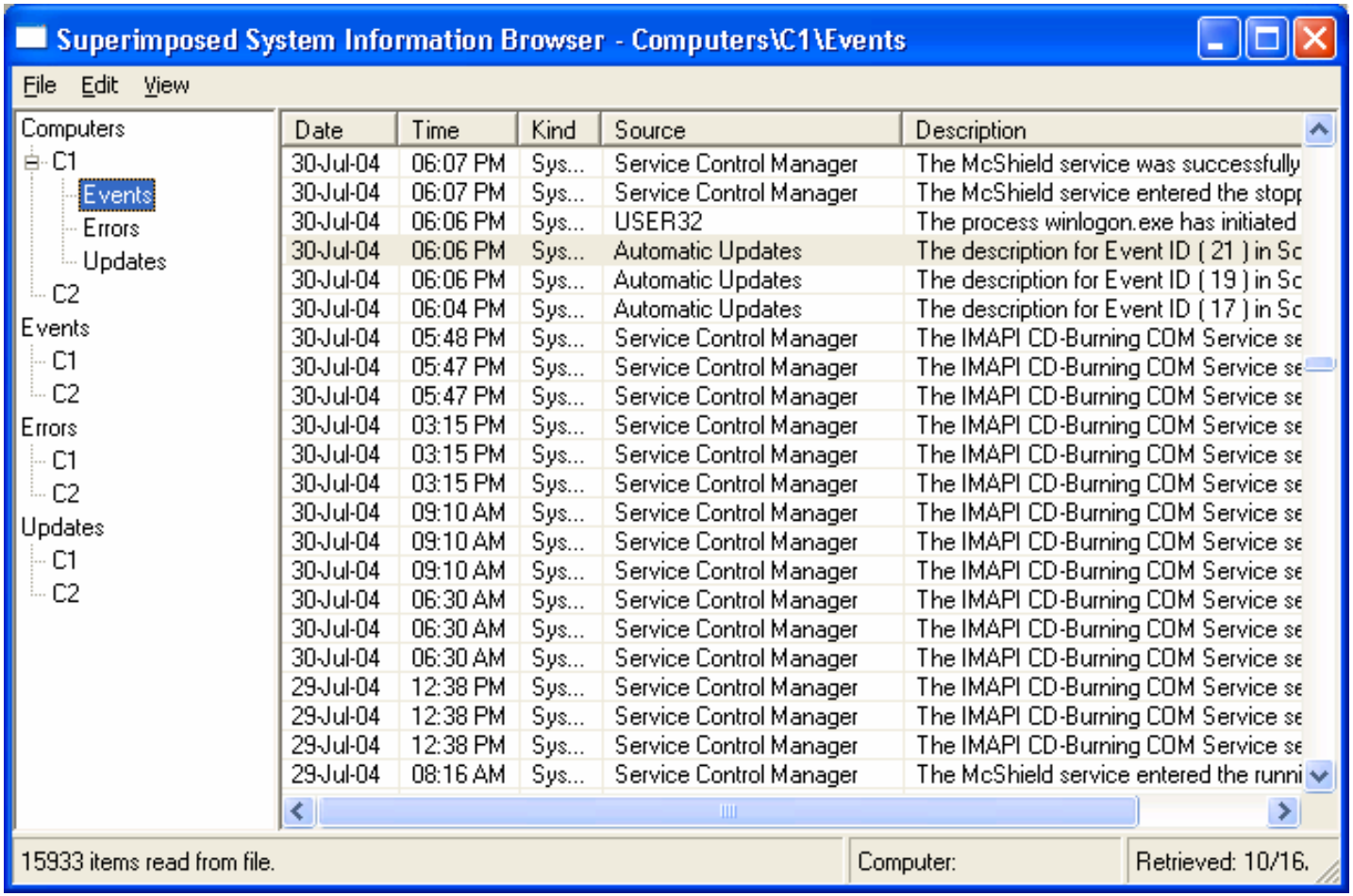
The Superimposed System-Information Browser

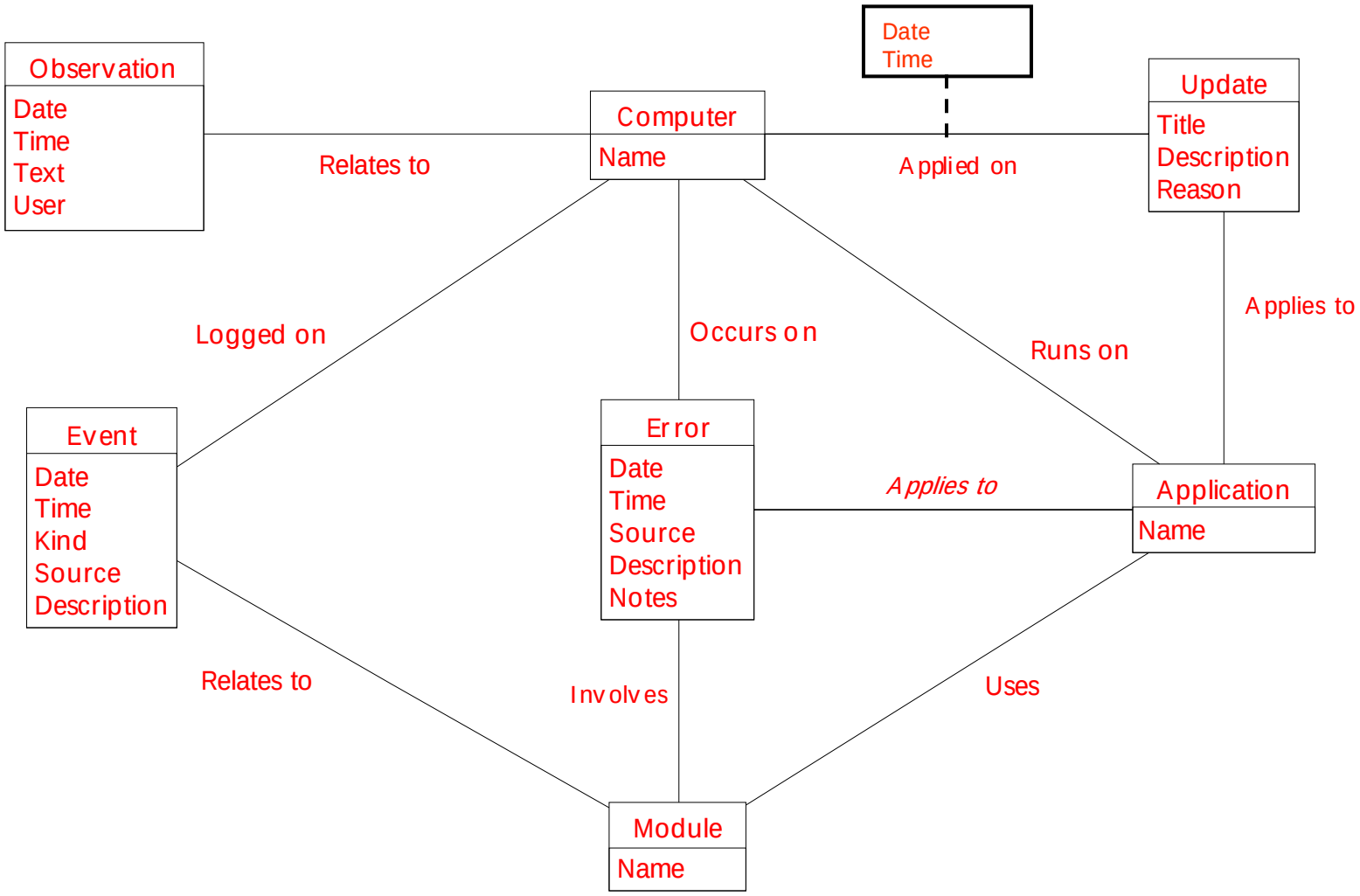
- Allows a system (network) administrator to browse information about computers in a network
  - Applications installed and the modules they use
  - Updates applied
  - Errors recorded/reported
  - Application, system, and security events logged
  - User observations/comments

The Browser


Superimposed System Information Browser - Computers\C1\Events
File Edit View
Computers
C1
Events
Errors
Updates
C2
Events
C1
C2
Errors
C1
C2
Updates
C1
C2
Date Time Kind Source Description
30-Jul-04 06:07 PM Sys... Service Control Manager The McShield service was successfully
30-Jul-04 06:07 PM Sys... Service Control Manager The McShield service entered the stopp
30-Jul-04 06:06 PM Sys... USER32 The process winlogon.exe has initiated
30-Jul-04 06:06 PM Sys... Automatic Updates The description for Event ID (21) in Sc
30-Jul-04 06:06 PM Sys... Automatic Updates The description for Event ID (19) in Sc
30-Jul-04 06:04 PM Sys... Automatic Updates The description for Event ID (17) in Sc
30-Jul-04 05:48 PM Sys... Service Control Manager The IMAPI CD-Burning COM Service se
30-Jul-04 05:47 PM Sys... Service Control Manager The IMAPI CD-Burning COM Service se
30-Jul-04 05:47 PM Sys... Service Control Manager The IMAPI CD-Burning COM Service se
30-Jul-04 03:15 PM Sys... Service Control Manager The IMAPI CD-Burning COM Service se
30-Jul-04 03:15 PM Sys... Service Control Manager The IMAPI CD-Burning COM Service se
30-Jul-04 03:15 PM Sys... Service Control Manager The IMAPI CD-Burning COM Service se
30-Jul-04 09:10 AM Sys... Service Control Manager The IMAPI CD-Burning COM Service se
30-Jul-04 09:10 AM Sys... Service Control Manager The IMAPI CD-Burning COM Service se
30-Jul-04 09:10 AM Sys... Service Control Manager The IMAPI CD-Burning COM Service se
30-Jul-04 06:30 AM Sys... Service Control Manager The IMAPI CD-Burning COM Service se
30-Jul-04 06:30 AM Sys... Service Control Manager The IMAPI CD-Burning COM Service se
30-Jul-04 06:30 AM Sys... Service Control Manager The IMAPI CD-Burning COM Service se
29-Jul-04 12:38 PM Sys... Service Control Manager The IMAPI CD-Burning COM Service se
29-Jul-04 12:38 PM Sys... Service Control Manager The IMAPI CD-Burning COM Service se
29-Jul-04 12:38 PM Sys... Service Control Manager The IMAPI CD-Burning COM Service se
29-Jul-04 08:16 AM Sys... Service Control Manager The McShield service entered the runni
15933 items read from file.
Computer:
Retrieved: 10/16.

* All entities have key attribute ID (not shown); all relationships are many-many

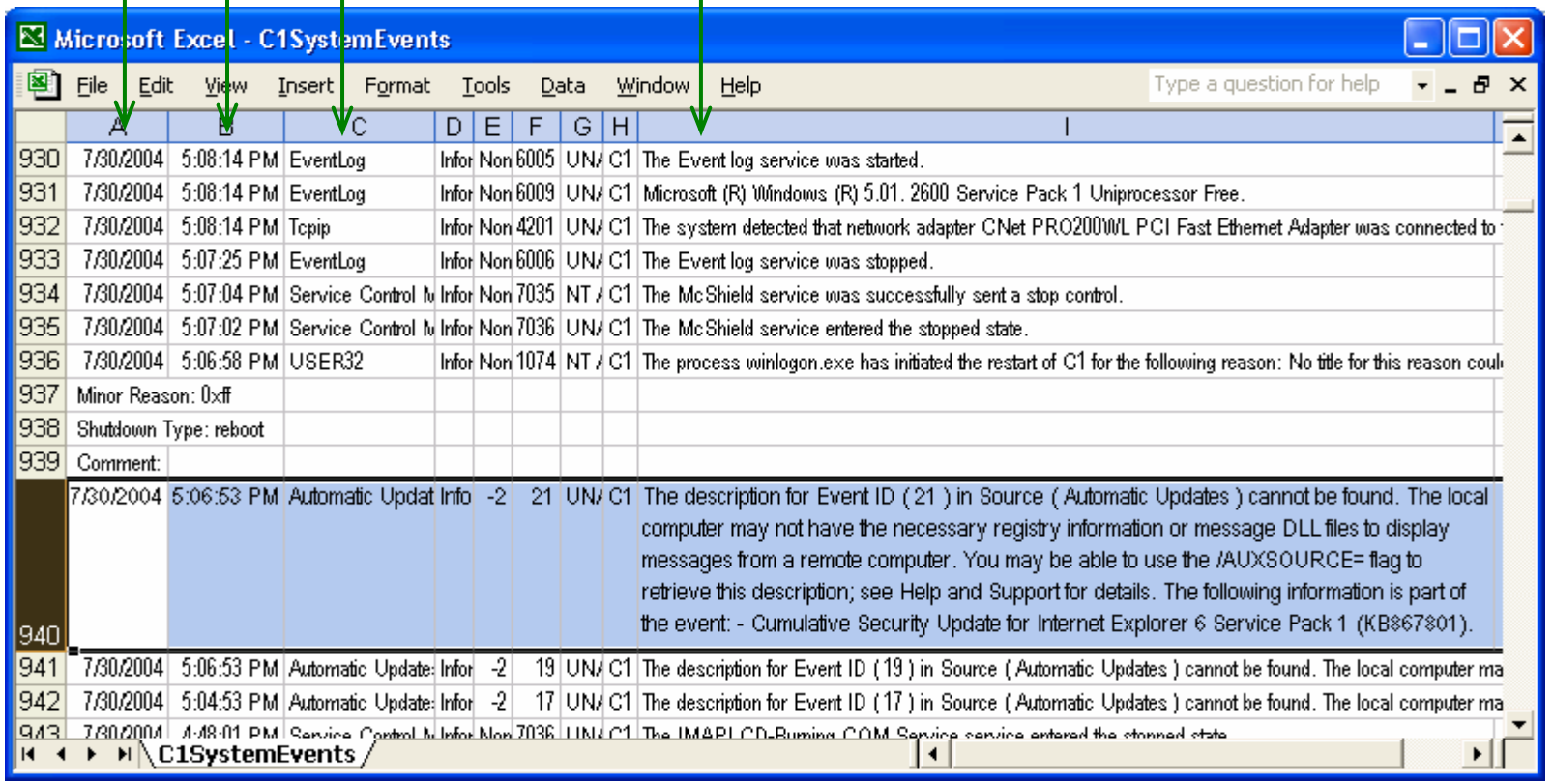
A Conceptual Schema*



Event Log

Event
Date
Time
Kind
Source
Description

Date **Time** **Source** **Description**

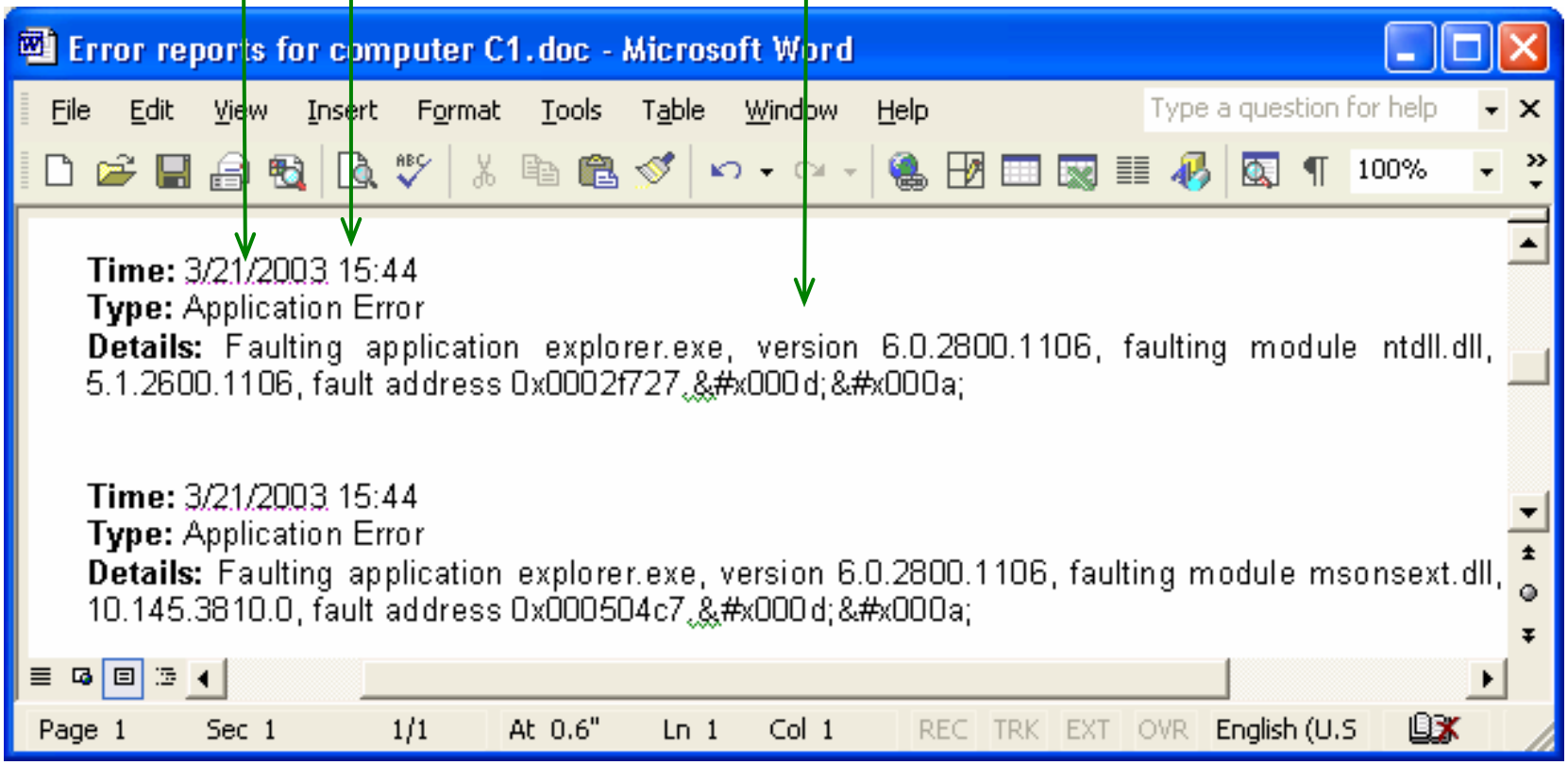


	A	B	C	D	E	F	G	H	I
930	7/30/2004	5:08:14 PM	EventLog	Infor	Non	6005	UNA	C1	The Event log service was started.
931	7/30/2004	5:08:14 PM	EventLog	Infor	Non	6009	UNA	C1	Microsoft (R) Windows (R) 5.01. 2600 Service Pack 1 Uniprocessor Free.
932	7/30/2004	5:08:14 PM	Tcpip	Infor	Non	4201	UNA	C1	The system detected that network adapter CNet PRO200WL PCI Fast Ethernet Adapter was connected to
933	7/30/2004	5:07:25 PM	EventLog	Infor	Non	6006	UNA	C1	The Event log service was stopped.
934	7/30/2004	5:07:04 PM	Service Control M	Infor	Non	7035	NT A	C1	The McShield service was successfully sent a stop control.
935	7/30/2004	5:07:02 PM	Service Control M	Infor	Non	7036	UNA	C1	The McShield service entered the stopped state.
936	7/30/2004	5:06:58 PM	USER32	Infor	Non	1074	NT A	C1	The process winlogon.exe has initiated the restart of C1 for the following reason: No title for this reason coul
937	Minor Reason: 0xff								
938	Shutdown Type: reboot								
939	Comment:								
940	7/30/2004	5:06:53 PM	Automatic Updat	Info	-2	21	UNA	C1	The description for Event ID (21) in Source (Automatic Updates) cannot be found. The local computer may not have the necessary registry information or message DLL files to display messages from a remote computer. You may be able to use the /AUXSOURCE= flag to retrieve this description; see Help and Support for details. The following information is part of the event: - Cumulative Security Update for Internet Explorer 6 Service Pack 1 (KB$67$01).
941	7/30/2004	5:06:53 PM	Automatic Update:	Infor	-2	19	UNA	C1	The description for Event ID (19) in Source (Automatic Updates) cannot be found. The local computer ma
942	7/30/2004	5:04:53 PM	Automatic Update:	Infor	-2	17	UNA	C1	The description for Event ID (17) in Source (Automatic Updates) cannot be found. The local computer ma

Some structural variations exist, but information is neatly in a table

Error Reports

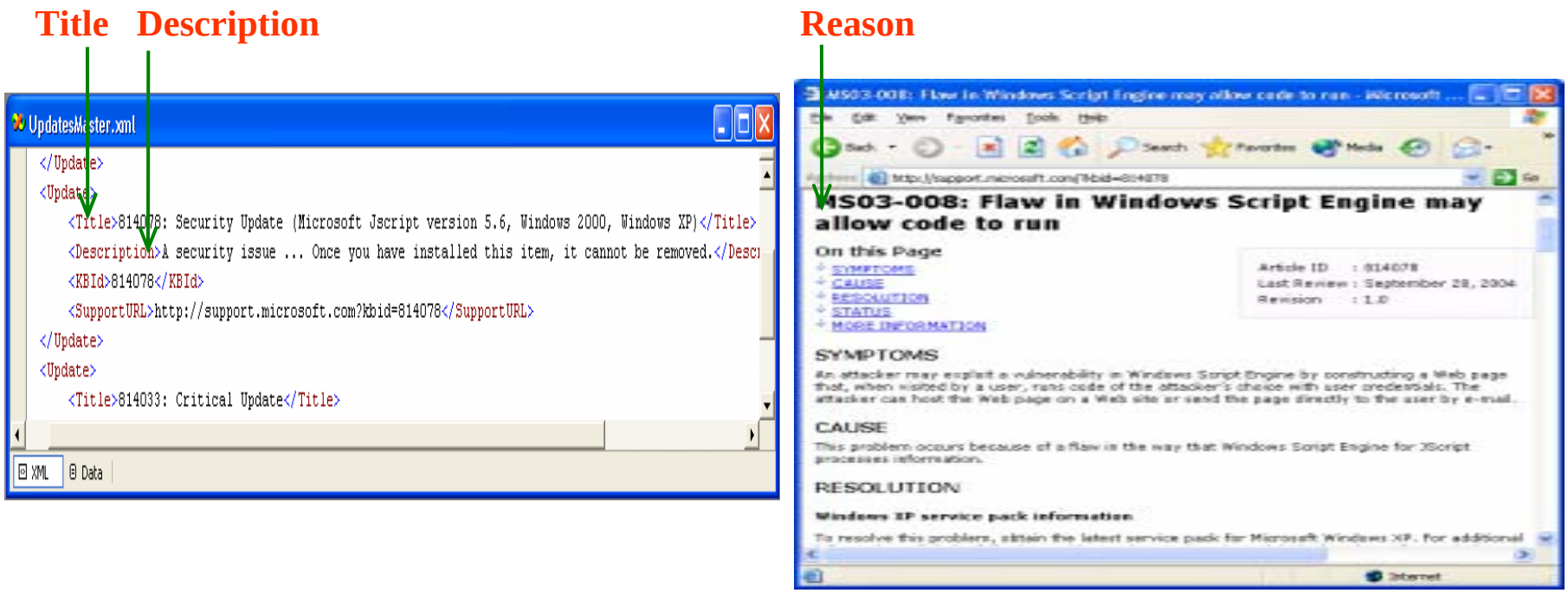
Error
Date
Time
Source
Description
Notes



Uniform structure, but mapping is not clean: Date and Time are both in Time field

Update

Update
Title
Description
Reason



Data is heterogeneous and distributed: some data in XML, some in HTML

Structure varies: support URL not always defined, HTML page structure varies widely

Observations

- Heterogeneous data models and schemas
  - Event logs are in MS Excel spreadsheets, Error reports in MS Word documents
- Distributed sources
  - Master list of updates is on the LAN, support pages are on the web
- The various data are interconnected
  - *Outlook errors stopped after SP2 was applied*
- The conceptual schema hides the heterogeneity and distribution, yet allows us to navigate the interconnections

The Problem

- The conceptual schema hides *too much*
- It does not make explicit the presence of external entities (*base information*) and the references to those entities (*marks*)
  - One consequence: any logical schema generated is incomplete (with respect to representation of information referenced)

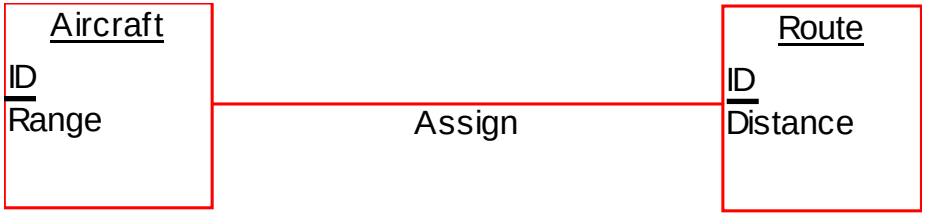
The Proposal

- Use a *relationship pattern language* to represent the use of marks
  - Identify and describe contexts for relationship patterns
  - Define schema-level and instance-level constraints
  - Fix syntax and semantics of relationship types
  - Describe consequences of relationships

Outline

- Motivation
- Some alternative solutions
- Overview of relationship patterns
- A relationship pattern language to represent the use of marks
- Conversion to logical model (relational model)
- Querying
- Summary

Model use of Mark as a Relationship



- Semantics of a relationship are mostly inferred from its name (and the definition of participating entities)
  - 'Assign' relates aircrafts and routes, but under what conditions should they be related?
- The traditional relationship does not completely capture the semantics of a mark
  - We need to distinguish between *inter-layer* and *intra-layer* relationships

ER Relationships Require Entities

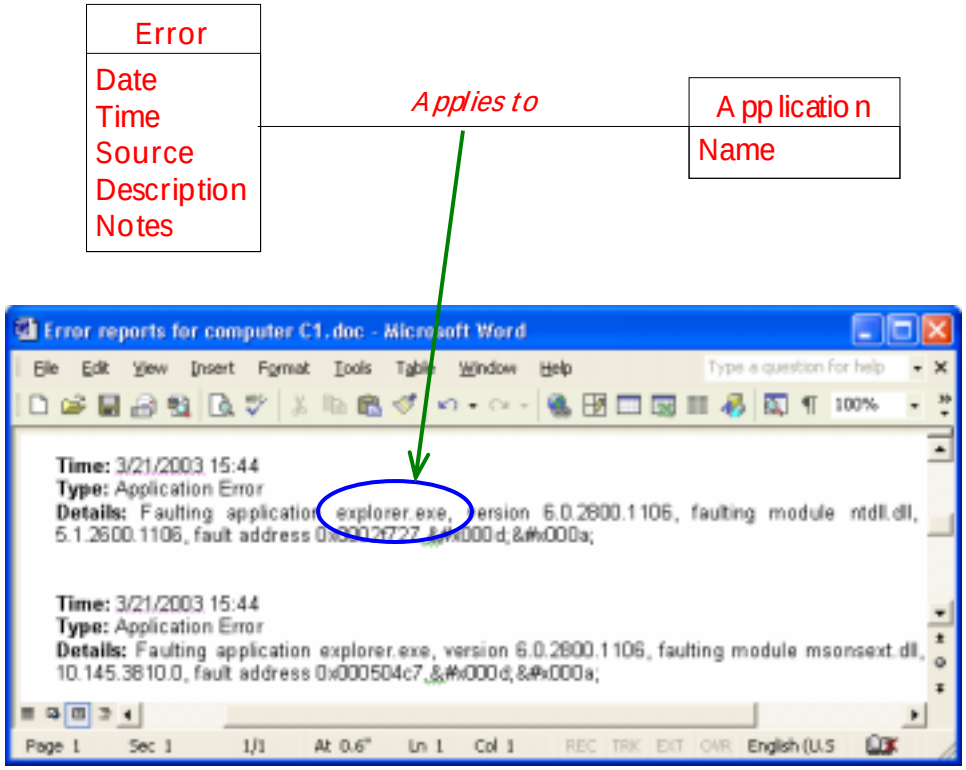
- ER relationships are between entities, but sometimes an attribute carries a reference (*e.g.*, Update.Title)
- Promoting attributes to entities, to show relationships, can cause entity proliferation (reduces comprehension)
  - The example schema has 12 such attributes
- Sometimes a group of attributes share a mark (*e.g.*, Error.Date and Error.Time)
  - Can be hard to define a key for an entity created for a group of attributes

Attribute Value

- In ER, no dereferencing is involved in obtaining an attribute's value, but obtaining a value from an attribute that uses a mark involves dereferencing
  - *E.g.*, Update.Title is the text excerpt of a mark
- Introducing a new domain such as 'Mark' does not suffice
  - We need to be able to distinguish between a value that is a mark and a value obtained using a mark

Supported Relationships

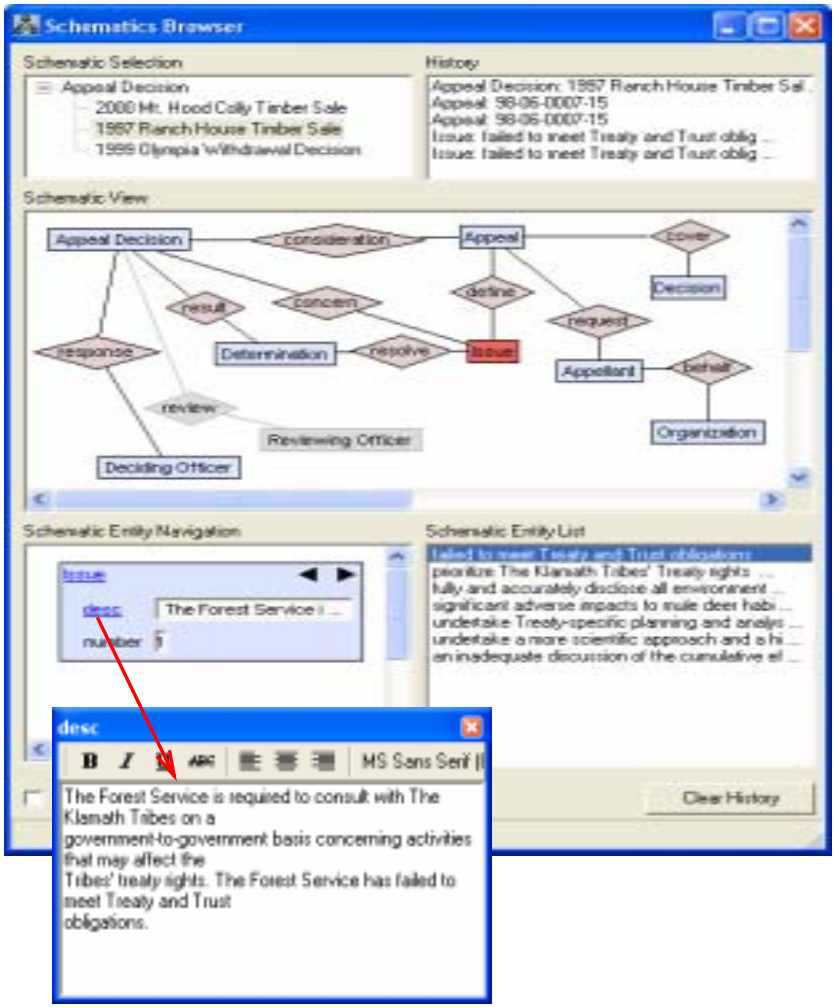
- Some relationships have *support*
  - An error applies to an application based on information in the details of the error report
- Traditional representation would use a relationship attribute



* Bowers, et al. Superimposed Schematics: Introducing E-R Structure for In-Situ Information Selections.

Superimposed Schematics*

- A *superimposed schematic* is an ER schema over base information
- *One* mark may be associated with an entity or a relationship
- Relationships *cannot* have attributes
- Introduces a *Mark* value type (?)



Our Approach

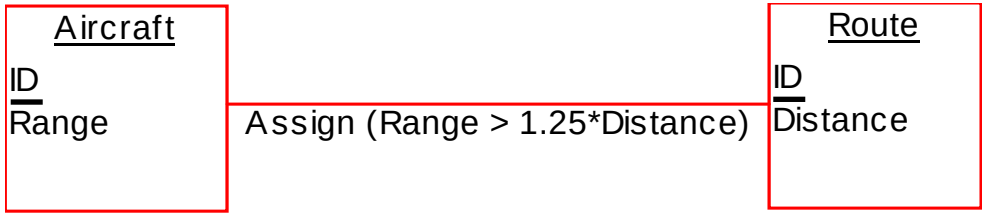
- Represent the use of a mark as a relationship
- We use relationship patterns to represent the use of marks
  - We define a relationship pattern language (a set of relationship patterns)
- No need for a ‘mark’ attribute or value type
  - That type can be added orthogonally

* Murthy, Maier. A Framework for Relationship Pattern Languages. 2005.

Relationship Patterns*

- A *relationship pattern* is an abstraction of *recurring* needs or problems when establishing relationships in a context; it can also be a *suggested* solution to the problems identified
- A relationship pattern is similar to a software pattern, except it is focused on relationships
- Like software patterns, inspired by the notion of patterns in architecture

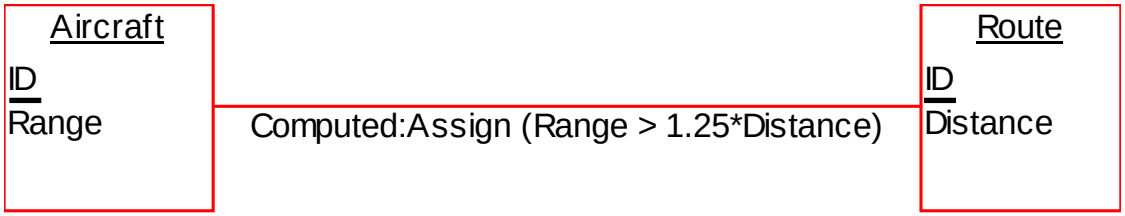
Example: The *Predicated* Relationship Pattern



`<type>(<predicate>)`

- `<type>` is name of a relationship type; `<predicate>` is a pre-condition for a relationship instance
- *E.g.*, An aircraft can be assigned to a route only if it can fly at least 25% farther than the route's distance

Example: The *Computed* Relationship Pattern



`Computed:<type>(<predicate>)`

- Relationship instances are *computed* (not stored)
  - Traditionally, relationship instances are stored
- Relationship must not have attributes, or they must be computable
- Creates the `Computed` *typespace*
  - A typespace is a set of related types

Relationship Signatures

- A relationship pattern defines a syntax to create the three text parts of a relationship type: names of typespaces and types, role names, structure of cardinality constraints
- Each of these three parts is defined using a *signature* (formally a grammar)
  - *E.g.*, `<type>(<predicate>)` is a type signature
- The three signatures together are called the *relationship signature*

Why Use Relationship Patterns?

- Solve a kind of problems once
- Describe many relationship types at once
- Understand many relationship types at once
- Customize
  - Define how relationships are treated in various stages of the information life cycle
- Leverage known patterns
  - Following a pattern well-understood can ensure consistency and increase acceptance

Benefits when Representing Use of Marks

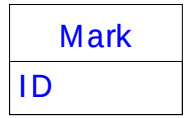
- Provide visual representation of the use of marks
- Any model element can be associated with marks (zero or more marks)
- Distinguish between a mark as a value and the use of a mark
- Provide a means to generate logical schema for superimposed and base information
  - Enables *bi-level querying* (over superimposed *and* base information, as if they are at the same level)

Representing the Use of Marks

Where can a Mark be?

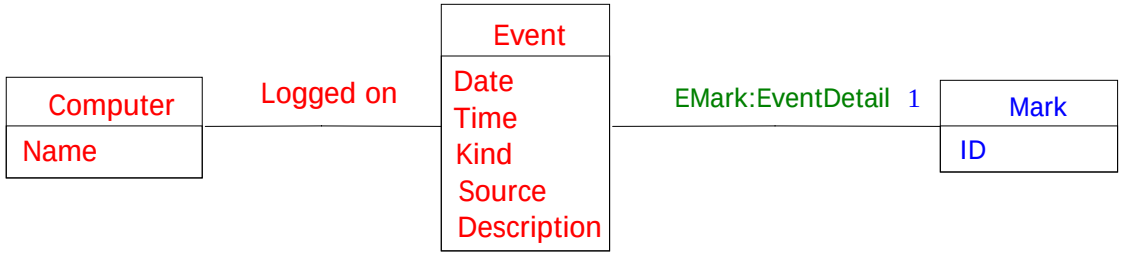
- Entity
  - *E.g.*, Event
- Relationship
  - *E.g.*, ‘Applies to’
- Entity and relationship attribute
  - *E.g.*, Update.Title and AppliedOn.Date

Modeling Marks



- The *Mark* entity models a mark
  - The ID attribute uniquely identifies a mark; all marks support the function *resolve*
  - The use of a mark is shown as a relationship with this entity
- All *inter-layer* relationships are between a superimposed entity and the Mark entity
  - *Intra-layer* relationships are between entities in a single layer: superimposed layer or base layer
  - Our focus is on inter-layer relationships

The *Entity-Mark* Pattern



- The EMark typespace contains relationship types that associate entities with marks
- EventDetail associates an Event entity with a mark
- ‘Logged on’ is a traditional relationship type

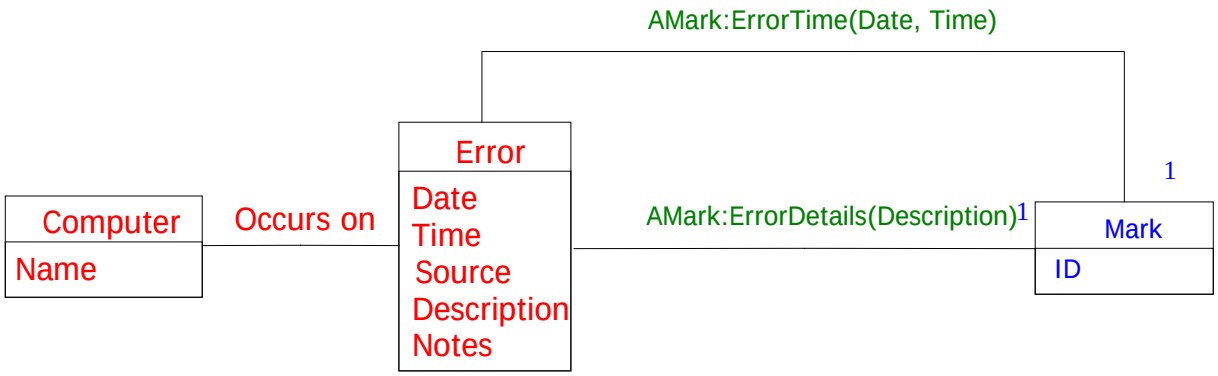
Entity-Mark Details

- Type Signature

  `EMark:<type>`

- Constraints
  - Entity type and degree: Any superimposed entity type; any number of superimposed entity types
  - Cardinality: Any
- Semantics
  - Superimposed entities are associated with marks
- Consequences
  - Conversion to relational model presented later

The *Attribute-Mark* Pattern



- The AMark typespace contains relationship types that associate attributes with marks
- ErrorDetails associates the Description attribute with a mark
- ErrorTime associates attributes Date and Time with one mark

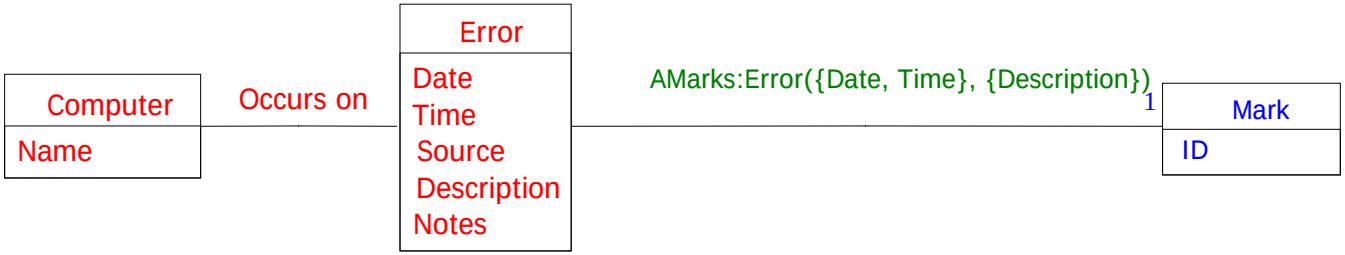
Attribute-Mark Details

- Type Signature

  AMark:<type>(a_1, a_2,…a_n)

- Constraints
  - $a_1, a_2, \ldots a_n$ (n>0) are *distinct* attributes of a superimposed entity
- Semantics
  - *All* attributes specified are associated with the *same* mark (or same bag of marks if cardinality is greater than 1)
  - Associating an attribute with a mark does *not* mean its value is obtained using the mark

Combining AMark Relationship Types



- The AMarks typespace lets you “combine” many AMark relationship types that involve the same entity type (but imposes a common name, and cardinality constraints)
- The ‘Error’ relationship type associates the Date and Time attributes with one mark, and the Description attribute with one mark

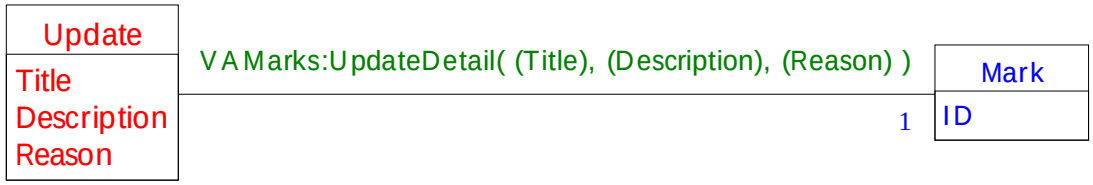
AMarks Details

- Type Signature

  AMarks:<type>(A_1, A_2,…A_n)

- Constraints
  - $A_1, A_2, \ldots A_n$ (n>0) are *non-empty*, *disjoint* sub-sets of the attributes of a superimposed entity
  - Attribute sets may be indicated using braces or parentheses
- Semantics
  - Each *set* of attributes is associated with *one* mark (or a bag of marks)

Deriving Attribute Values from Marks



- An attribute might *always* derive its value from a mark's context (*e.g.*, excerpt)
- The VAMark and VAMarks typespaces define relationship types for this purpose
- UpdateDetail associates the value of each of the attribute Title, Description, and Reason with the context of a mark

VAMark Details

- Type Signature

  VAMark:<type>(a_1, a_2,…a_n)

- Constraints
  - $a_1, a_2, \ldots a_n$ (n>0) are *distinct* attributes of a superimposed entity
  - Cardinality *must* be 1 (single-valued attributes)
- Semantics
  - *All* attributes specified are associated with *one* mark, and their values are derived from that mark's context
- Consequences: Requires casting/type checking

VAMarks Details

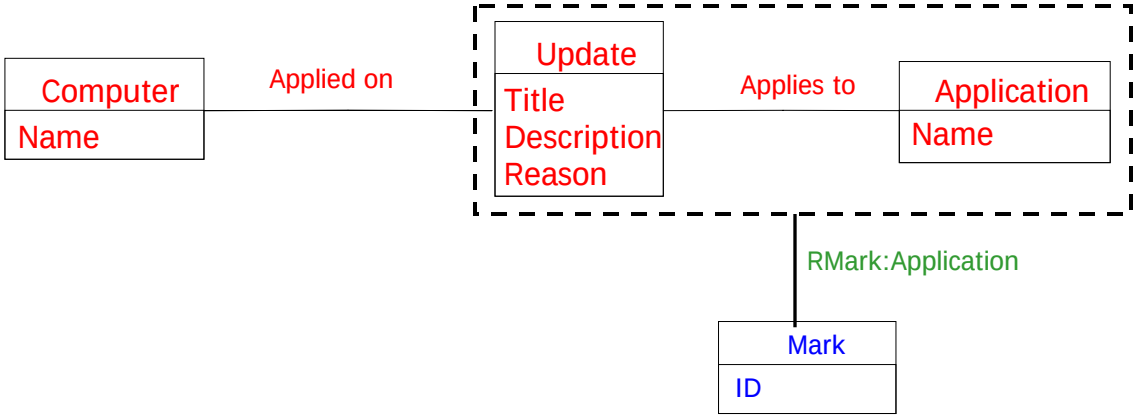
- Type Signature

  VAMarks:<type>(A_1, A_2,…A_n)

- Constraints
  - $A_1, A_2, \ldots A_n$ (n>0) are *non-empty*, *disjoint* sub-sets of the attributes of a superimposed entity
  - Cardinality *must* be 1
- Semantics
  - Each *set of attributes* is associated with *one mark*
  - Use of context is similar to that in the VAMark typespace

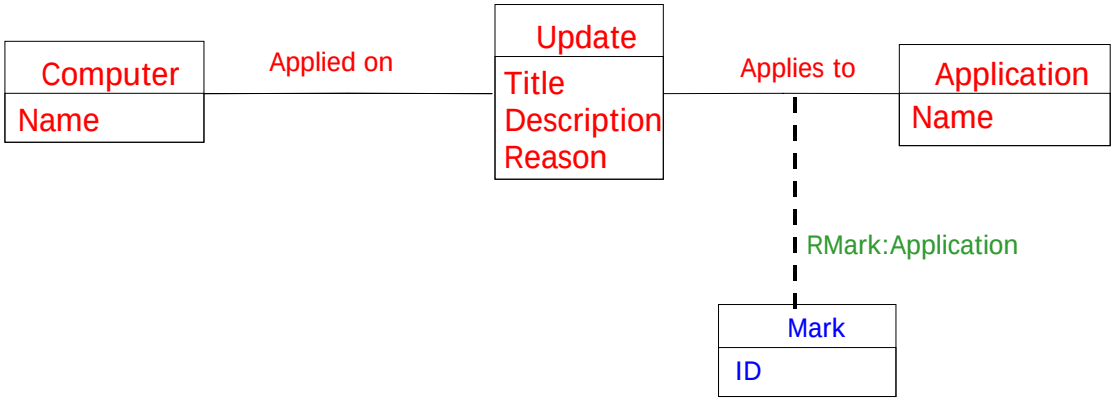
* Ramakrishnan and Gehrke. Database Management Systems, 3rd Ed.

The *Relationship-Mark* Pattern



- Aggregate* the relationship to be associated with marks (called *supported relationship*)
- Add an RMark relationship with the aggregate
- The 'AppliesTo' relationship type is first aggregated. RMark:Application associates the aggregate with marks

Avoiding Drawing Aggregates



- We draw a dotted line from the supported relationship (*e.g.*, ‘Applies to’) to the Mark entity instead of drawing an aggregate entity
  - The dotted line clarifies that the degree of the supported relationship is unchanged

Relationship-Mark Details

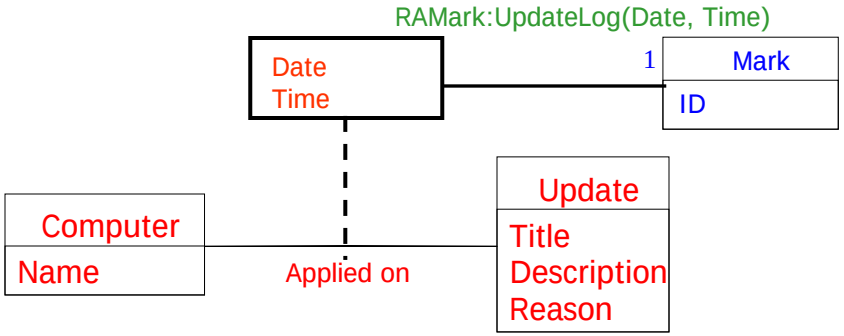
- Type Signature

  `RMark:<type>`

- Constraints on the supported relationship
  - Can be inter-layer or intra-layer
  - Can be of any type, degree, and cardinality
  - Can have attributes
- Constraints on RMark relationship type
  - Always *binary*
  - Can have attributes

* An update log stores details of applications of updates to computers

Associating Relationship Attributes with Marks



- The RAMark typespace contains relationship types that associate relationship attributes with marks
- UpdateLog* associates both attributes Date and Time with one mark

RAMark Details

- Type Signature

  RAMark:<type>(a_1, a_2,…a_n)

- Constraints
  - $a_1, a_2, \ldots a_n$ (n>0) are *distinct* attributes of a superimposed entity
- Semantics
  - *All* attributes specified are associated with *one* mark (or a bag of marks)
  - Associating an attribute with a mark does *not* mean its value is obtained using the mark

RAMarks Details

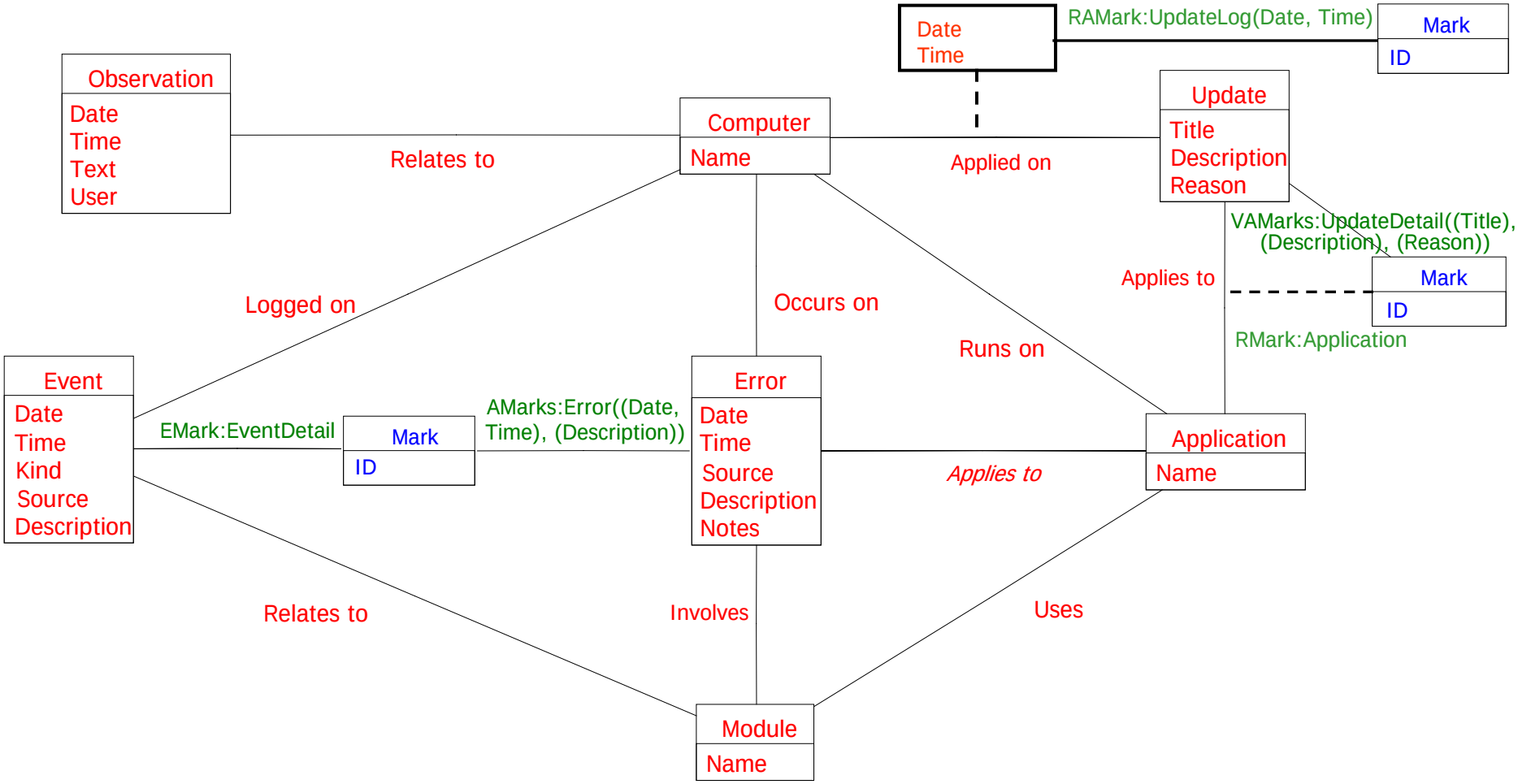
- Type Signature

  RAMarks:<type>(A_1, A_2,…A_n)

- Constraints
  - $A_1, A_2, \ldots A_n$ (n>0) are *non-empty*, *disjoint* sub-sets of the attributes of a superimposed entity
  - Attribute sets may be indicated using braces or parentheses
- Semantics
  - Each *set of attributes* is associated with *one* mark (or a bag of marks)

* EMark, AMarks, VAMarks, and RAMark relationships are many-1; other relationships are many-many

Revised Conceptual Schema*



Conversion to Relational Model

Converting the Mark Entity

- The Mark entity type is represented as a table with attributes such as
  - ID: Integer (key)
  - CreatedOn: Date
  - CreatedBy: String
  - CreateAt: String
- The attributes are derived from the *SPARCE* mark descriptor

*Elmasri, Navathe. Fundamentals of Database Systems, 4th Ed.

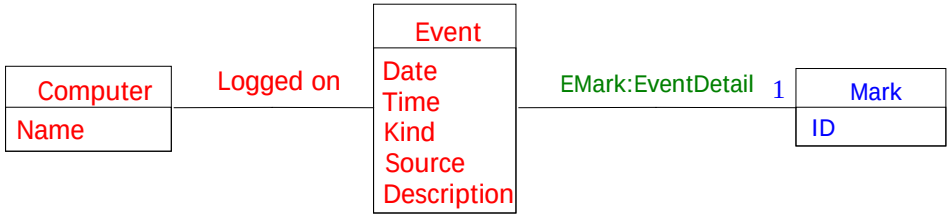
Converting EMark Relationship Types

- Convert the relationship type and the superimposed entity type using the traditional procedure*
- Derive the name for the foreign-key attribute that references Mark.ID from the name of the relationship type.
  - *E.g.*, EMark_EventDetail

*Added ID attribute (for all relations). Altered names of attributes Date and Time

Example EMark Conversion

```
CREATE TABLE Event
( ID Integer NOT NULL PRIMARY KEY,
  EDate Date, ETime Time,
  Kind CHAR(5),
  Source VARCHAR(25),
  Description VARCHAR(255),
  EMark_EventDetail Integer NOT NULL
     REFERENCES Mark(ID)
)
```

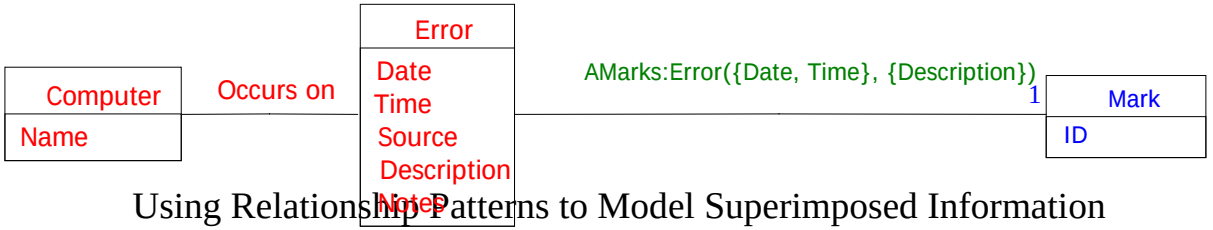


Converting AMark(s) Relationship Types

- AMark: Convert the relationship type and superimposed entity type using the traditional procedure
- AMarks: For each set of attributes in the parameters
  - Follow the procedure to convert AMark relationship types

Example AMarks Conversion

```
CREATE TABLE Error
( ID Integer NOT NULL PRIMARY KEY,
  EDate Date, ETime Time,
  AMark_Error_DT Integer NOT NULL
     REFERENCES Mark(ID),
  Source VARCHAR(25),
  Description VARCHAR(255),
  AMark_Error_Desc Integer NOT NULL
     REFERENCES Mark(ID),
  Notes VARCHAR(255)
)
```



*The procedure might not preserve key constraints if a key attribute is associated with a mark

Converting VAMark Relationship Types*

- Follow the procedure to convert AMark relationship type
- Replace each attribute associated with a mark, with an integer attribute
  - The replacement attribute stores the ID of the context element that supplies the original attribute's value
  - Alternative: remove the attribute, specify the context element ID in view definition (if value is *always* derived from the *same* context element)
- Define a view

*Alternatively, context element IDs can also be directly specified in the view definition

Defining a View

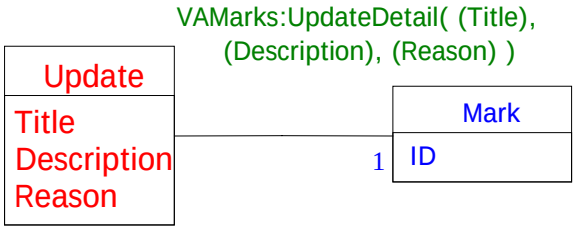
- The schema of the view matches the entity's
- For each attribute associated with a mark, embed call to the function *context*
  - The attribute that represents the associated mark supplies the mark ID
  - The attribute that represents the associated context element supplies the context element ID*
- We assume the view inserts a NULL value in case of a type mismatch (possible if function *context* returns an incompatible type)

Converting VAMarks Relationship Types

- For each set of attributes in the parameters
  - Follow the procedure to convert VAMark relationship types

Example VAMarks Conversion

```
CREATE TABLE Stored_Update
( ID Integer NOT NULL PRIMARY KEY,
  VAMark_TitleCElm Integer,
  VAMark_Title Integer NOT NULL
     REFERENCES Mark(ID),
  VAMark_DescCElm Integer,
  VAMark_Desc Integer NOT NULL
     REFERENCES Mark(ID),
  VAMark_ReasonCElm Integer,
  VAMark_Reason Integer NOT NULL
     REFERENCES Mark(ID)
)
```



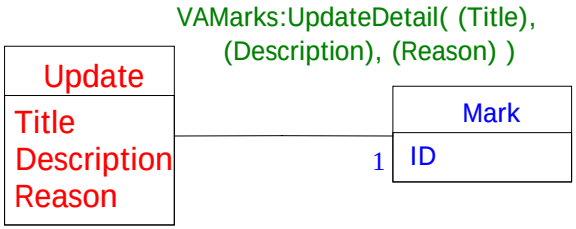
Example View Definition

```
CREATE VIEW Update (ID, Title,
  Description, Reason) AS
SELECT
ID,
context(VAMark_Title, VAMark_TitleCElm),
context(VAMark_Desc, VAMark_DescCElm),
context(VAMark_Reason, VAMark_ReasonCElm)
FROM Stored_Update
```

- **context** is a user-defined function

Example Alternative VAMarks Conversion

```
CREATE TABLE Stored_Update
( ID Integer NOT NULL PRIMARY KEY,
  VAMark_Title Integer NOT NULL
     REFERENCES Mark(ID),
  VAMark_Desc Integer NOT NULL
     REFERENCES Mark(ID),
  VAMark_Reason Integer NOT NULL
     REFERENCES Mark(ID)
)
```



Example Alternative View Definition

```
CREATE VIEW Update (ID, Title,
  Description, Reason) AS
SELECT
ID,
context(VAMark_Title, e1),
context(VAMark_Desc, e2),
context(VAMark_Reason, e3)
FROM Stored_Update
```

- e1, e2, e3 are IDs of context elements

*Cardinality of the RMark relationship type is 1; cardinality of the original relationship type is immaterial

Converting RMark Relationship Types (1)*

- Convert the original relationship type and the related entity types using an *appropriate* procedure (the original relationship might *not* be traditional)
- To the table that captures the original relationship type
  - Add a foreign key attribute that references Mark.ID
  - Add attributes of the RMark relationship type

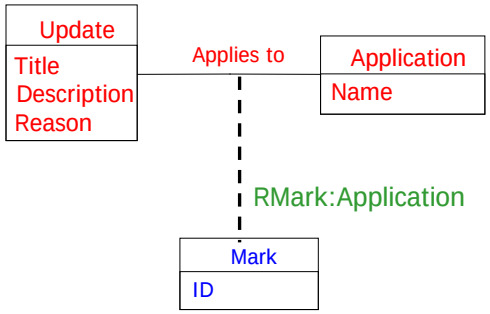
*Cardinality of the RMark relationship type is many

Converting RMark Relationship Types (Many)*

- Convert the original relationship type and the related entity types using an appropriate procedure
- Create a new table (derive name from the RMark relationship type). To the new table:
  - Add the key of the table that captures the original relationship type, and make it a foreign key
  - Add a foreign key attribute that references Mark.ID
  - Define primary key as set of foreign key attributes
  - Add attributes of the RMark relationship type

* In the running example, Update information is stored in table Stored_Update

Example RMark (Many) Conversion




```
CREATE TABLE Stored_Update*
( ID Integer…, PRIMARY KEY ID)
CREATE TABLE Application
( ID Integer…, PRIMARY KEY ID)
CREATE TABLE AppliesTo
( UID Integer…, AID Integer…, PRIMARY KEY
  (UID, AID))
CREATE TABLE RMark_Application
( UID Integer…, AID Integer…,
  RMarkID Integer
     REFERENCES Mark(ID),
  PRIMARY KEY (UID, AID, RMarkID))
```

*Cardinality of the RAMark relationship type is 1

Converting RAMark Relationship Types (1)*

- Convert the original relationship type and the related entity types using an appropriate procedure
- To the table that captures the original relationship type
  - Add a foreign key attribute that references Mark.ID
  - Add attributes of the RAMark relationship type

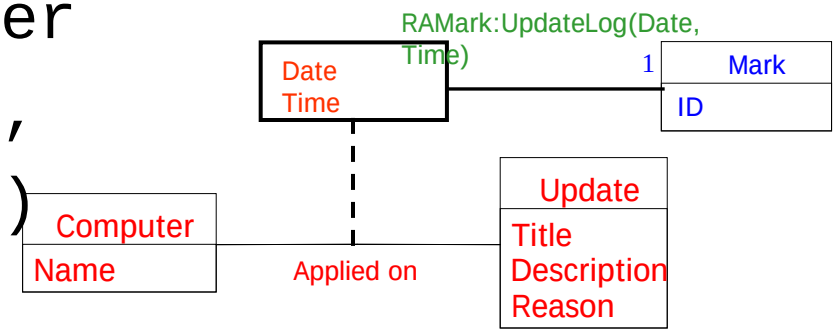
*Cardinality of the RAMark relationship type is many

Converting RAMark Relationship Types (Many)*

- Convert the original relationship type and the related entity types using an appropriate procedure
- Create a new table (derive name from the RAMark relationship type). To the new table:
  - Add the key of the table that captures the original relationship type, and make it a foreign key
  - Add a foreign key attribute that references Mark.ID
  - Define primary key as set of foreign key attributes
  - Add attributes of the RAMark relationship type

Example RAMark (1) Conversion

```
CREATE TABLE Stored_Update
( ID Integer…, PRIMARY KEY ID)
CREATE TABLE Computer
( ID Integer…, PRIMARY KEY ID)
CREATE TABLE AppliedOn
( UID Integer…, AID Integer…,
  EDate As Date, ETime As Time,
  RAMark_UpdateLog Integer
     REFERENCES Mark(ID),
  PRIMARY KEY (UID, AID))
```



Using Views

When to use Views

- If an attribute *always* gets its value from the context of a mark
- When *live* base data is needed

- The VAMark and VAMarks typespaces automatically generate view definitions
  - We describe the use of views for “black belts”

Creating View Definitions

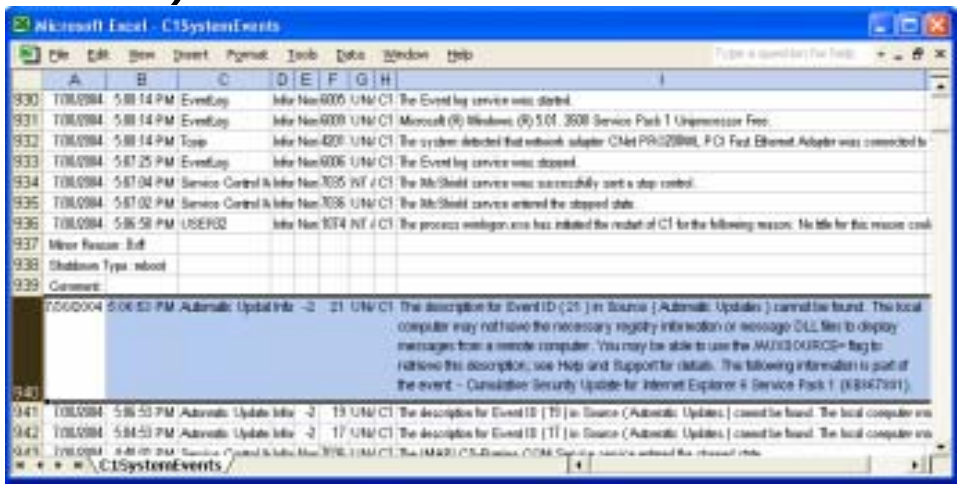
- Create a stored relation containing *only* the foreign key attributes that reference Mark.ID, and the attributes whose values are *not* derived from context of marks
  - Alternatively, replace an attribute that derives value from a mark's context with an integer attribute that stores the context element ID
- Create a view over the stored relation with embedded calls to the function *context* (a user-defined SQL function) to compute values of attributes omitted from the stored relation

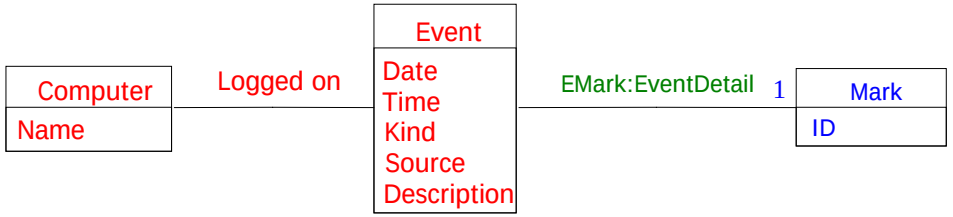
*Application knowledge tells us that all but the ID and Kind attributes get their values from a mark's context

Example Stored Relation: Event

```
CREATE TABLE Stored_Event
( ID Integer NOT NULL PRIMARY KEY,
  Kind CHAR(5),
  EMark_EventDetail Integer NOT NULL
     REFERENCES Mark(ID)
)
```

*Attributes EDate, ETime, Source, and Description are removed**





*e1, e2, e3, e4 are IDs of context elements

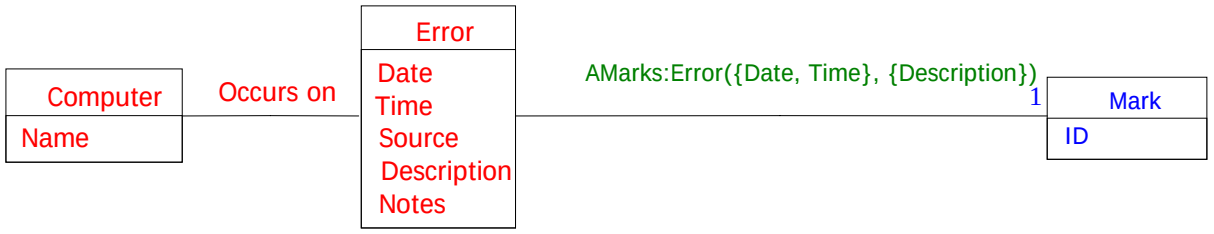
Example View Definition: Event*

```
CREATE VIEW Event (ID, Date, Time, Kind,
  Source, Description) AS
SELECT
  ID,
  context(EMark_EventDetail, e1),
  context(EMark_EventDetail, e2),
  Kind,
  context(EMark_EventDetail, e3),
  context(EMark_EventDetail, e4)
FROM Stored_Event
```

Example Stored Relation: Error

```
CREATE TABLE Stored_Error
( ID Integer NOT NULL PRIMARY KEY,
  Source VARCHAR(25),
  Notes VARCHAR(255),
  AMark_Error_DT Integer NOT NULL
     REFERENCES Mark(ID),
  AMark_Error_Desc Integer NOT NULL
     REFERENCES Mark(ID)
)
```

Attributes EDate, ETime, and Description are removed



*e1, e2, e3 are IDs of context elements

Example View Definition: Error*

```
CREATE VIEW Error (ID, Date, Time,
  Source, Description, Notes) AS
SELECT
  ID,
  context(AMark_Error_DT, e1),
  context(AMark_Error_DT, e2),
  Source,
  context(AMark_Error_Desc, e3),
  Notes
FROM Stored_Error
```

Querying

Bi-level Queries

- *Bi-level queries* can be written against the logical schema
- A query can freely use the function *context* with a mark ID and a context element ID
  - This function returns *live* data from the base layer (under normal circumstances)
  - Can assign the result of this function to an attribute
  - Can use function *excerpt* to retrieve text excerpt
- View definitions provide the best abstraction

Example Queries 1, 2

- Retrieve all update details
  ```
  SELECT * FROM Update
  ```
- Retrieve updates related to security
  ```
  SELECT * FROM Update
  WHERE Description LIKE 'Security%'
  ```
- Because `Update` is a view, values of attributes associated with mark are retrieved from the base layer when the view definition is executed

Example Query 3

- Retrieve all errors MS Word caused in the last week

```
SELECT * FROM Error
WHERE EDate BETWEEN CURRENT_DATE AND
  CURRENT_DATE - INTERVAL '6' DAY
AND Description LIKE '%Word.exe%'
```

- If `Error` is a view, the attributes date, time and description are retrieved from the base layer when the view definition is executed

Example Query 4

- Create a timeline of errors related to MS Word and MS Outlook

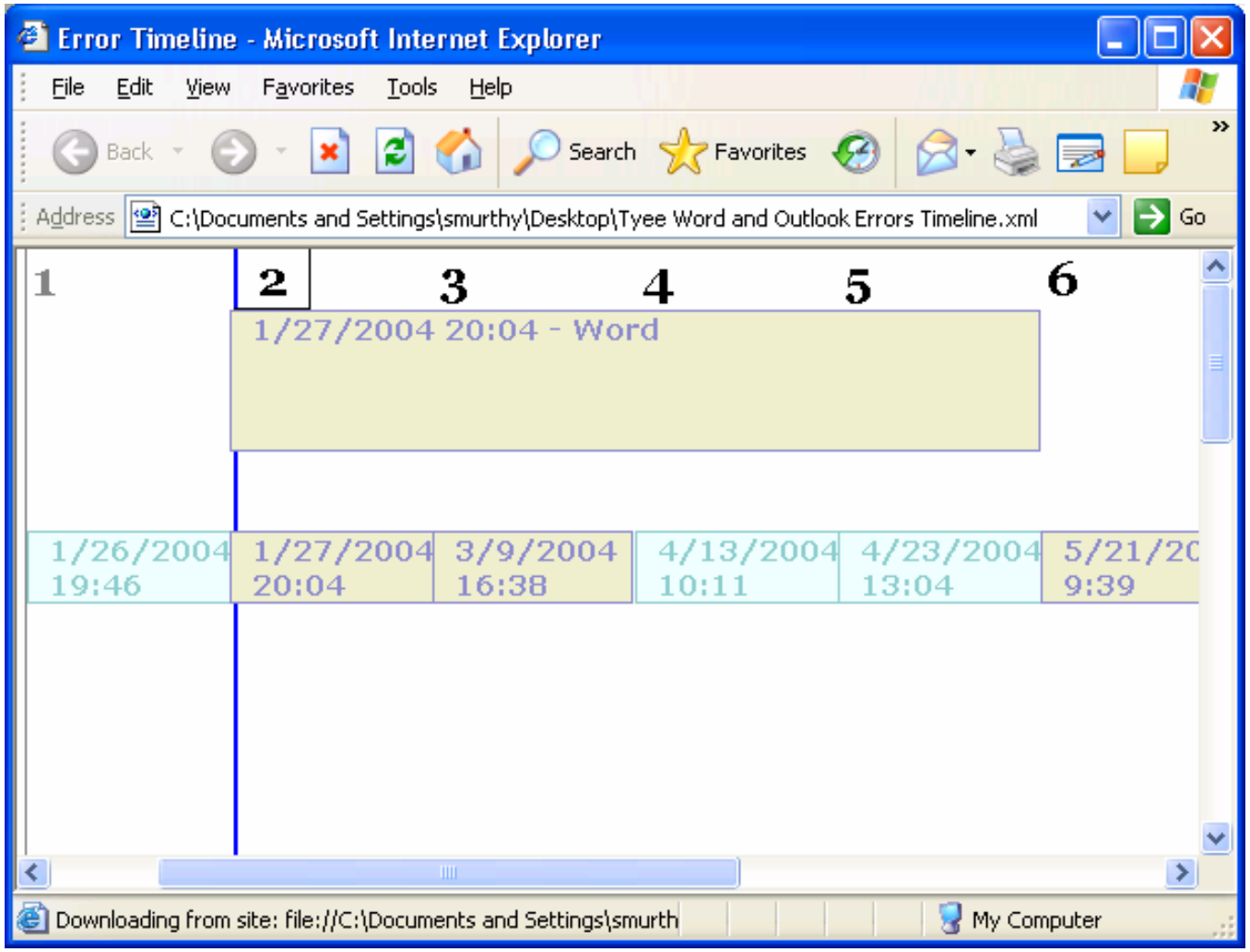
```
SELECT EDate, ETime, Description
FROM Error
WHERE Description LIKE '%word.exe%'
OR Description LIKE '%Outlook.exe%'
```

Sample Results 4

EDate	ETime	Description
1/26/2004	19:46	Hanging app…Outlook.EXE…
1/27/2004	20:04	Faulting app…winword.exe…
3/9/2004	16:38	Hanging app…winword.EXE
4/13/2004	10:11	Faulting app…Outlook.EXE…
4/23/2004	13:04	Hanging app…Outlook.EXE…
5/21/2004	9:39	Faulting app…winword.exe…
5/26/2004	14:05	Faulting app…winword.exe…

*Drawn using an XML transformation based on work of Nicolas Kruchten. Timeline is non-linear

Timeline 4*



Example Query 5

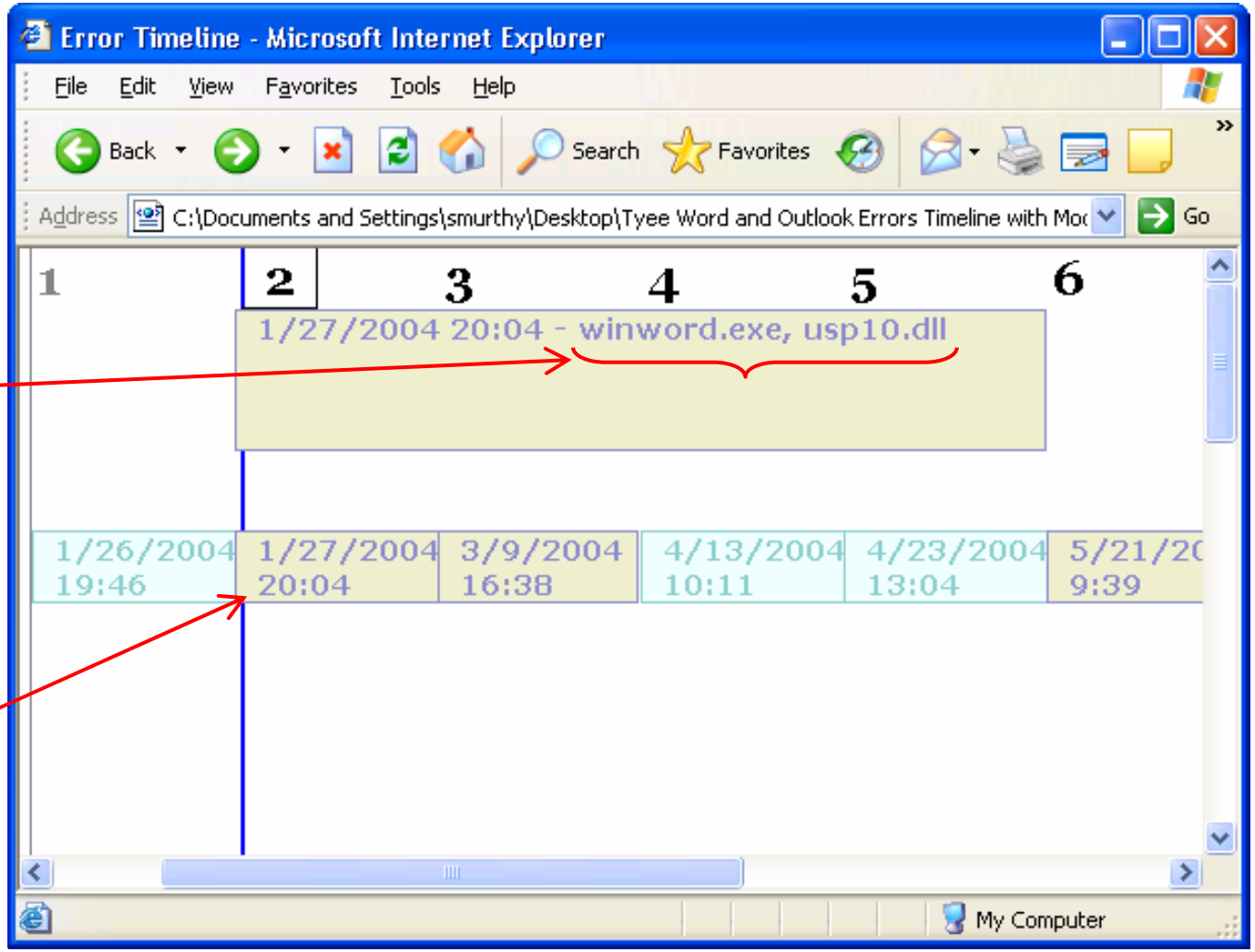
- Create a timeline of errors, along with the faulting application and module

```
SELECT EDate, ETime,
 SUBSTRING(Description SIMILAR
  '\"%\" application \"%\", \"%\"’
  ESCAPE '\'),
 SUBSTRING(Description SIMILAR
  '\"%\" module \"%\", \"%\"’ ESCAPE
  '\')
FROM Error
```

Sample Results 5

EDate	ETime	#1	#2
1/26/2004	19:46	Outlook.EXE	hungapp
1/27/2004	20:04	winword.exe	usp10.dll
3/9/2004	16:38	winword.EXE	WINWORD.EXE
4/13/2004	10:11	Outlook.EXE	ntdll.dll
4/23/2004	13:04	Outlook.EXE	hungapp
5/21/2004	9:39	winword.exe	winword.exe
5/26/2004	14:05	winword.exe	mso.dll

Timeline 5



Application and module information retrieved from context

Date and time information retrieved from context

Example Query 6

- What events related to Outlook are recorded after SP2 update was applied?

```
SELECT
 E.EDate, E.Time, E.Description
FROM Event E, Update U JOIN AppliedOn A
  On U.ID=A.UID
WHERE U.Description LIKE '%SP 2%'
AND E.EDate > A.EDate
AND E.Description LIKE '%Outlook.exe%'
```

Updates applied

SP 2 Update

Events after SP 2 is applied

Outlook events

Summary

- Associating marks with entities, attributes, and relationships is a recurring need. That is, there are patterns involving use of marks
- We have identified key aspects for patterns of using marks: contexts, constraints, syntax, semantics, and consequences
- We have shown how to generate relational schema from a conceptual schema
- We have demonstrated some bi-level queries

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