NASSI-SHNEIDERMAN DIAGRAMS AND TABLETALK

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1. Introduction

There is a growing interest in the subject of visual languages, as evidenced by a spate of new publications in the area (including two new books [1,2]) and the birth of a new journal devoted to the subject.

At last year's Vision Interface / Graphics Interface Conference, this author presented a paper on "informatics calculus", a graphical query language for multi-media database systems [3]. "Informatics calculus" has been revised and has been renamed "TableTalk". The syntax of the language has been formalized in terms of syntax diagrams and the semantics has been recast in terms of sequences, objects and their transformations. TableTalk represents an effort to capture all "database activities" in a seamless, visual language. Seamless implies that regardless of the activity, the database user will be operating within the same conceptual and visual framework. Accomplishing this is a major challenge, since database activities are quite diverse. With respect to the writing of applications programs, the fundamental issue for TableTalk is whether a graphical, functional query language can be integrated into a framework which supports applications programming? This paper proposes that this can be accomplished by combining TableTalk with another diagrammatic language, Nassi-Shneiderman (N-S) diagrams.

2. Nassi-Shneiderman diagrams and graphical query languages

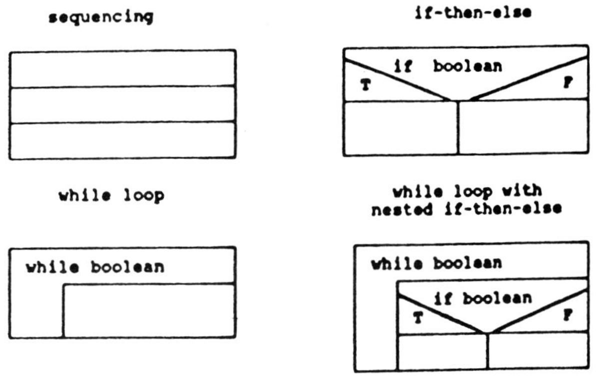
Shu [1] presents an excellent introduction to visual languages. Other introductions to this topic are found in Chang [4] and in Ambler and Burnett [5]. Our specific interest is in visual languages which allow people to program by means of visual expressions. Representative examples of such systems include PICT/D [6], N-S diagrams [7] and all graphical query languages.

Experience with visual programming systems such as PICT/D has shown that in order to make a visual language cost effective, the visual expressions in the language must correspond to concepts in a very high level programming language. Graphical query languages generally adhere to this principle.

The term "N-S diagrams" refers to a family of very similar diagrammatic notations whose common idea is to express structured programming control structures in diagrammatic form. N-S diagrams, like TableTalk, express programs as mosaics, that is, as rectangular arrangements of non-overlapping tiles. Spatial patterns are used to denote various kinds of combinators.

N-S diagrams represent a higher level of program abstraction than the icons and flowcharts of PICT/D. N-S diagrams are also far less demanding in terms of computer graphics resources. Thus, they represent a practical approach to facilitating program development. N-S diagrams have been employed by a variety of systems, including IBM's Programming Support System [8], PIGS [9] and GRASE [10]. Figure 1 presents some of the basic tiling patterns employed in N-S diagrams.

Figure 1. Tiling patterns employed by N-S diagrams



Graphical query languages generally operate at a higher level of abstraction than N-S diagrams. Data models have encouraged the development of very powerful, non-procedural, database languages whose fundamental feature is that they describe "programming in the large". For example, the relational data model [11] has fostered the development of a great variety of database languages, both textual and graphical. Some of these are based upon relational algebra (e.g., ASTRID [12]), others are based upon relational calculus (e.g., QUEL [13] and QBE [14]) and yet others are designed around slightly different formalisms (e.g., SQL [15]). Shipman's functional data model [16] gave rise to a powerful functional query language, FQL (see Buneman et al. [17]) and the TableTalk language [3], which captures the semantics of a functional query language in diagrammatic terms.

A review of graphical query languages reveals a great diversity in terms of their use of visual information to communicate the underlying database semantics. (See Shu [1], chapters 2 and 11, and also the proceedings of the IEEE Workshop on Visual Languages, including Czejdo, Reddy et al., [18] and Rohr [19].) An interesting discussion of available means for expressing semantics in visual languages is given in Selker and Koved [20]). QBE [14], CUPID [21], ISIS [22], FORMAL [23], and GUL-Q [24] represent a variety of approaches for expressing database semantics in a graphical query language.

There are several fundamental challenges inherent in graphical query language design. These include:

1. Basing the query language on a suitable user-centered data model which can be mapped to the underlying logical model.
2. Employing an effective visual metaphor for expressing database semantics.
3. Achieving orthogonality.
4. Mirroring thought (expressiveness, completeness).
5. Supporting multi-media.
6. Supporting extensibility.
7. Providing a uniform system image across the various database activities (including data definition, querying, updating, report generation and applications programming).
8. Supporting problem decomposition as a problem-solving aid.

Providing a uniform system image across various database activities (challenge #7, above) is certainly a formidable task. IBM's relational database system DB2 is typical in this regard (see Date [25]). Although IBM supports QBE as a user-oriented, graphical interface to DB2, QBE does not mesh with the applications development language (which is COBOL!). Applications programs are written in COBOL with embedded SQL.

3. TableTalk: A graphical, functional query language

This section presents a brief synopsis of the TableTalk language. TableTalk is based upon a semantic data model. Appendix A presents most of the basic elements of TableTalk's semantic data model and Appendix B shows the semantic database schema assumed throughout the rest of this paper. TableTalk's data model represents a compromise between Hammer and McCleod's original semantic data model [26] and Shipman's functional data model [16].

Here are some essential facts about TableTalk:

1. TableTalk is a functional query language.
2. TableTalk expresses functional programs as mosaics.
3. TableTalk is a sequence processing language.

TableTalk's underlying formalism derives from Buneman's functional query language, FQL [17]. FQL and TableTalk express queries as functional forms which are built up from primitive elements (including entity classes, attributes and constants) using functional combinators (such as composition and Cartesian product). TableTalk uses various visual elements to express functional combinators. For example, functional composition can be expressed by means of vertical juxtaposing of tiles, Cartesian product is expressed by means of horizontal juxtaposing of tiles, and subqueries are expressed using mosaics embedded within tiles. In addition, external functional forms can be referenced by name. In such a situation, the functional form referred to is substituted into the functional form in which the reference occurs. Figure 2 summarizes the basic tiling patterns of TableTalk.

TableTalk is a sequence processing language. This means that the semantics of the language is formally described in terms of sequences of objects. An object encapsulates one or more pieces of information. There are four kinds of objects: scalar objects, set objects, entity objects and sequences. These correspond to the four kinds of attributes in the underlying model: single-valued scalar, multi-valued scalar, single-valued entity and multi-valued entity attributes. An entity object encapulates information about some entity in the database. Figure 3 presents graphical representations for the four kinds of objects. (The visual representation of an object is called a "card".) An entity object can be either primordial or non-primordial. For example, a primordial book object encapsulates all of the information associated with a particular book. Since this is potentially an infinite amount of information (due to cyclic patterns in the database schema), the encapsulated information is represented symbolically as an "entity

Figure 2. Basic tiling patterns in TableTalk

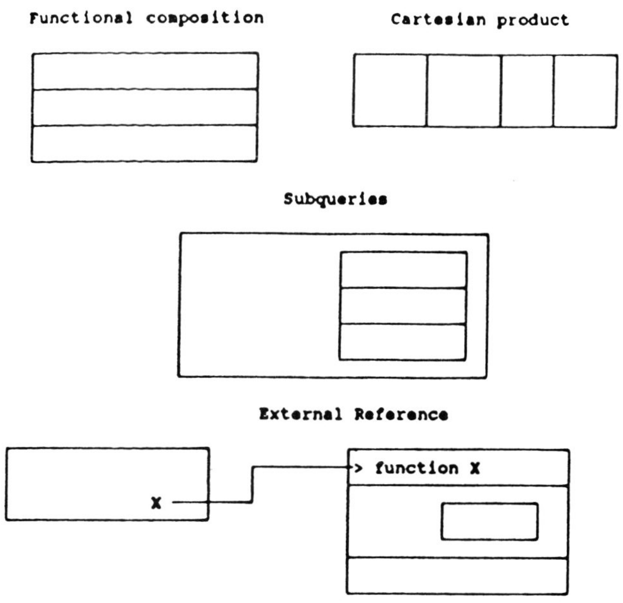
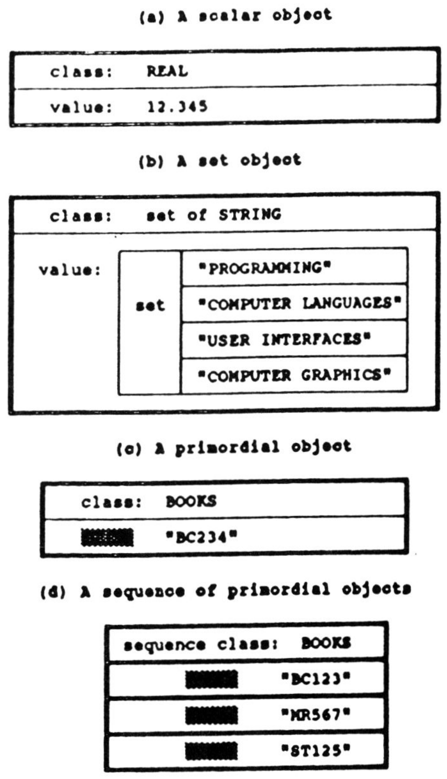


Figure 3. Cards for various kinds of objects.



button": ▨ . A non-primordial book object is a book object that has had some of its information filtered out (usually by a process similar to the relational algebraic operation of "projection"). A non-primordial book object can contain other entity objects, either primordial or non-primordial. Figure 4 shows a card for a non-primordial book object.

Figure 4. Card for a non-primordial book object which contains two scalar objects, a primordial entity object and a sequence of primordial objects.

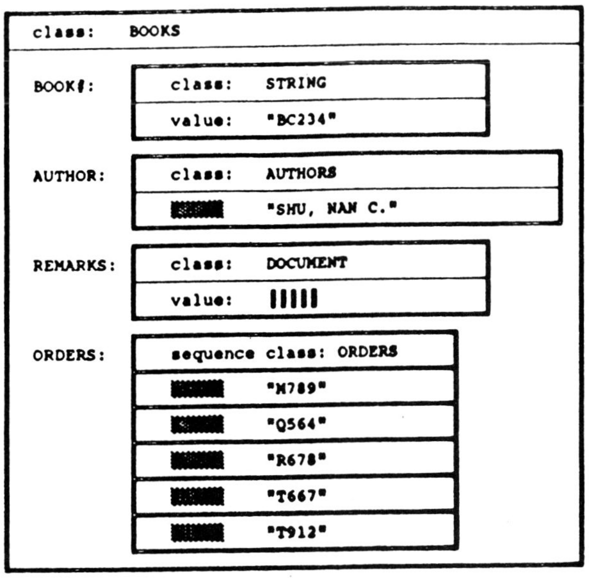


Figure 5. The basic kinds of rows and what they do.

row type:	action performed:
entity class / subclass	transforms the null sequence into a sequence of primordial objects from the specified class.
predicate	removes from the input sequence any object which does not satisfy the predicate
functional	replaces a sequence of numbers with a single number
functor	rearranges the input sequence in some way
product	transforms primordial objects into non-primordial objects by filtering out attributes

Every TableTalk query can be viewed as a sequence of "rows". Each row belongs to a particular syntactical category (determined by the formal syntax of the language, which is given in [27]). Each row can be viewed as transforming an input sequence. It is important to realize that each row describes an iterative process, the iteration being over the objects in the input sequence. The kind of transformation performed by a row depends upon the syntactic category of that row. The major kinds of rows are summarized in Figure 5.

3.1 Query sublanguage examples

This section presents a sequence of TableTalk query sublanguage examples.

Example 1. Give the book numbers, author names and photos, for books whose price is less than $10.00.

Row			
1	BOOKS		
2	PRICE < 10.0		
3	BOOK#	AUTHOR	
		NAME	PHOTO
	BC234	SHU, NAN C.	▮▮▮▮▮
	ML897	DATE, CHRIS	▮▮▮▮▮
	UH543	KROENKE, DAVID	▮▮▮▮▮

In this case, row 1 is an entity class, row 2 is a predicate and row 3 is a product. The result of the query is the sequence of three non-primordial book objects which are displayed in tabular form beneath the double line. The ▮▮▮▮▮ symbol under the PHOTO column represents a "scalar button" which provides access to an author's photo.

Example 2. Give the book numbers, titles, order numbers, and customers for those orders for books published by Addison-Wesley that are out of stock.

BOOKS			
and	IN_STOCK = 0		
	NAME of PUBLISHER = "ADDISON-WESLEY"		
BOOK#	TITLE	ORDERS	
		ORDER#	CUSTOMER

The second row of Example 2 is a predicate which is of the form

and	B1
	B2

where B1 and B2 are boolean expressions. The second boolean expression involves a "derived attribute". A derived attribute is an attribute which is the composition of two or more attributes contained in the database schema. In this case, NAME of PUBLISHER represents the composition of the attributes

```
  PUBLISHER : BOOKS   -----> PUBLISHERS
and
  NAME      : PUBLISHERS ---> STRING.
```

TableTalk uses the reserved word **of** to denote functional composition on the left and the reserved word **'s** to denote functional composition on the right. Hence, NAME of PUBLISHER and PUBLISHER 's NAME denote the same derived attribute.

Example 3. Give the average price of books written by Chris Date and published by Addison-Wesley.

BOOKS	
and	AUTHOR 's NAME is "DATE, CHRIS"
	PUBLISHER 's NAME is "ADDISON-WESLEY"
PRICE	
average	

Example 4.

Give the title, price and number in stock of all books either written by Chris Date or published by Addison Wesley and give these in alphabetical order by title.

BOOKS		
or	AUTHOR 's NAME is "DATE, CHRIS"	
	NAME of PUBLISHER is "ADDISON-WESLEY"	
sort by TITLE		
TITLE	PRICE	IN_STOCK

Example 5.

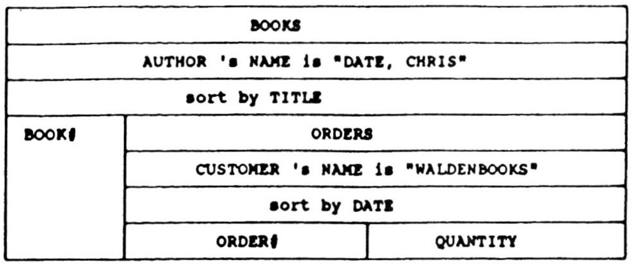
Give the book numbers, titles and author's names for all books not written by Chris Date but published by Addison-Wesley that are more expensive than the cheapest book written by Chris Date.

BOOKS		
and	PUBLISHER 's NAME is "ADDISON-WESLEY"	
	NAME of AUTHOR is not "DATE, CHRIS"	
	PRICE >	BOOKS
		AUTHOR 's NAME is "DATE, CHRIS"
		PRICE
		minimum
BOOK#	TITLE	AUTHOR 's NAME

The second row of Example 5 is a predicate of the form B1 and B2 and B3, where Bj, j = 1, 2, 3 are boolean expressions. The third boolean expression includes a subquery. This subquery returns a single scalar object, whose value is the lowest price charged for any book written by Chris date. In the third row (a product), the derived attribute AUTHOR 's NAME could also have been expressed as:

AUTHOR
NAME

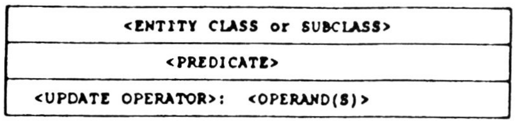
Example 6.
Give book numbers and order information for books written by Chris Date. We want the book information sorted by title. We only want orders placed by Waldenbooks and we want the orders for each book sorted by date. We want the order numbers and the quantities ordered for each book.


BOOKS
AUTHOR 's NAME is "DATE, CHRIS"
sort by TITLE
BOOK#
ORDERS
CUSTOMER 's NAME is "WALDENBOOKS"
sort by DATE
ORDER#
QUANTITY

Example 6 illustrates the recursive syntax and semantics of the TableTalk language. The multi-valued entity attribute ORDERS yields, for each book, a sequence of order objects. TableTalk treats all sequences, whether at the top level (i.e., the main processing sequence) or at a lower level (e.g., a sequence within an object), in a consistent manner. Example 6 applies a predicate and a functor (**sort by**) to the sequence of orders contained within each book object in the main processing sequence.

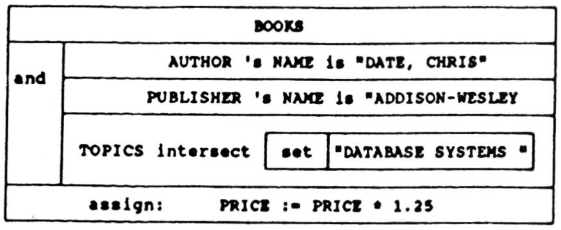
3.2 Update sublanguage examples

The general form for a database update is shown below:



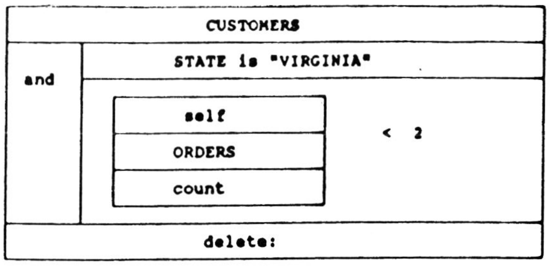
The update operators include **assign**, **input**, **delete**, and **insert**. Each operator has its own set of legal operands.

Example 7.
Increase the price of all books published by Addison-Wesley and written by Chris Date which discuss database systems by 25%.


BOOKS
and
AUTHOR 's NAME is "DATE, CHRIS"
PUBLISHER 's NAME is "ADDISON-WESLEY
TOPICS intersect
set
"DATABASE SYSTEMS "
assign: PRICE := PRICE * 1.25

The second boolean expression in the predicate row of Example 8 includes a subquery which begins with the reserved word **self**. This subquery is re-computed for each individual customer object in the main processing sequence. The value of the subquery is the number of orders for the current customer.

Example 8. Delete all customers who live in Virginia who have placed fewer than two orders.



4. Integrating TableTalk and N-S diagrams

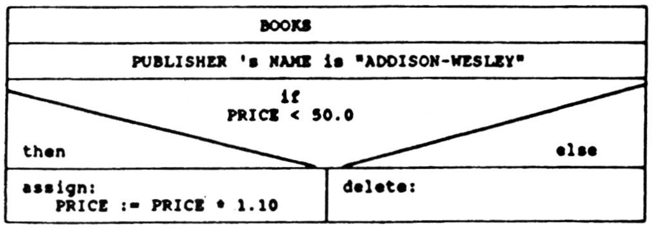
TableTalk and N-S diagrams share the use of mosaics as a means of representing programs. A TableTalk mosaic represents a program in a functional query language and an N-S diagram represents a program in an imperative language. We propose a melding of TableTalk mosaics and N-S diagrams as a means of achieving a multi-paradigmic, diagrammatic language for specifying database applications. The tiling metaphor can act as a bridge between the functional programming paradigm of TableTalk and the imperative paradigm of N-S diagrams.

Integrating TableTalk and N-S diagrams involves solving three fundamental problems:

1. Incorporating N-S notation into the TableTalk language.
2. Incorporating TableTalk into the N-S language.
3. Providing a mechanism for the functional language to communicate with the imperative language, and visa versa.

<u>Problem 1</u>. The TableTalk syntax needs to be extended to include N-S diagrammatic notations. Example 10 illustrates how such an extension to TableTalk might be accomplished. The third row of this TableTalk update is an if-then-else structure which determines which update operation (**assign** or **delete**) is applied to books in the processing sequence.

Example 10.
Increase the price of all books published by Addison-Wesley by 10% if the current price is under $50.00 and delete all book published by Addison-Wesley whose price is over $50.00.

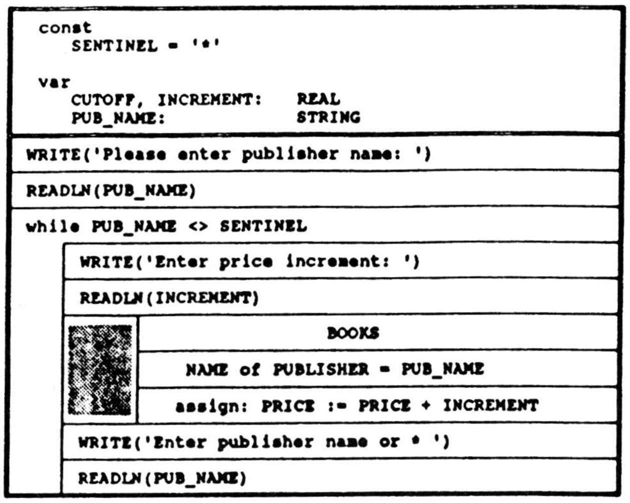


<u>Problem 2</u>. N-S diagrams need to be extended in order to allow for embedded TableTalk mosaics. Example 11 shows an N-S diagram which includes an embedded TableTalk update. The embedded TableTalk update is bounded on the left by a shaded

border to distinguish it from the imperative language elements.

Example 11.

This program allows the user to increase the prices of all books published by certain publishers by a certain increment. A sentinel loop is used. When the user enters an asterisk for the publisher's name, the loop terminates.



```
const
   SENTINEL = '*'

var
   CUTOFF, INCREMENT:   REAL
   PUB_NAME:            STRING

WRITE('Please enter publisher name: ')
READLN(PUB_NAME)
while PUB_NAME <> SENTINEL
      WRITE('Enter price increment: ')
      READLN(INCREMENT)
                        BOOKS
          NAME of PUBLISHER = PUB_NAME
          assign: PRICE := PRICE + INCREMENT
      WRITE('Enter publisher name or * ')
      READLN(PUB_NAME)
```

Problem 3. TableTalk is a sequence processing language. Iteration over objects in a sequence is automatic. Some device is needed to allow the imperative language to express iterations over TableTalk sequences. In embedded SQL this is accomplished by means of cursors. Cursors allow an imperative language to process the results of a query record by record. This enables fine-grained interactions between the imperative language and the database language. A similar device will be necessary in the final specification of the integrated TableTalk / N-S language.

5. Summary and conclusions

This paper presented Tabletalk as a database language and did not discuss the implementation of the user-interface. Tabletalk is intended to be implemented as a highly interactive system with extensive help facilities. In particular, the user will not need to have an in-depth knowledge of the database schema. Randy Kirsh at Temple University is currently implementing a small subset of TableTalk in order to explore the relationship between such a schema-based help facility and the language structure.

Visual languages, in order to be cost effective, must allow programmers to work at a high level of abstraction. Unfortunately, most languages which operate on a very high level of abstraction, such as database query languages, lack flexibility and generality. Consequently, there is little commonality between end-user interfaces and the languages which are used to develop applications.

This paper points out the similarities between TableTalk, a functional, graphical query langugage, and N-S diagrams, a family of diagrammatic languages for specifying control structures in imperative languages. The paper concludes by presenting some tentative ideas concerning how TableTalk and N-S diagrams can be integrated in order to yield a diagrammatic applications programming language.

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APPENDIX A

BASIC KINDS OF OBJECTS IN TABLETALK'S SEMANTIC DATA MODEL

kind of object	example of this kind of object given in Appendix b
ENTITY CLASS	BOOKS
SUBCLASS	BEST_SELLERS
SCALAR CLASS	STRING
ENTITY ATTRIBUTE	the (multi-valued) entity attribute: ORDERS: BOOKS ----->> ORDERS
SCALAR ATTRIBUTE	the (single-valued) scalar attribute: BOOK#: BOOKS ------> STRING
DERIVED ATTRIBUTE	the attribute: NAME of AUTHOR: BOOKS ------> STRING
INVERSE ATTRIBUTES	the attributes: ORDERS: BOOKS ------>> ORDERS BOOKS: ORDERS ----->> BOOKS
INTERSECTION ATTRIBUTE	the attribute: QUANTITY: (BOOKS p ORDERS) ------> NUMBER

APPENDIX B

SCHEMA DIAGRAMS ASSUMED BY TABLETALK EXAMPLES IN THIS PAPER

This appendix presents the database schema which is assumed in all examples given in this paper. Figure B.1 shows the database schema in terms of entity classes, subclasses and their relationships. Figure B.2 shows individual entity classes and subclasses and their scalar attributes.

Entity classes and subclasses are denoted using boxes. Scalar classes are denoted using ovals. Multi-valued attributes are denoted using double-headed arrows and single-valued attributes are denoted using single-headed arrows. Inverse attributes are connected by a single line, which might have an intersection attribute emanating from it. QUANTITY is a single-valued scalar intersection attribute.

Figure B.1

The database schema in terms of entity classes, subclasses and their relationships. Also shown is the intersection attribute, QUANTITY.

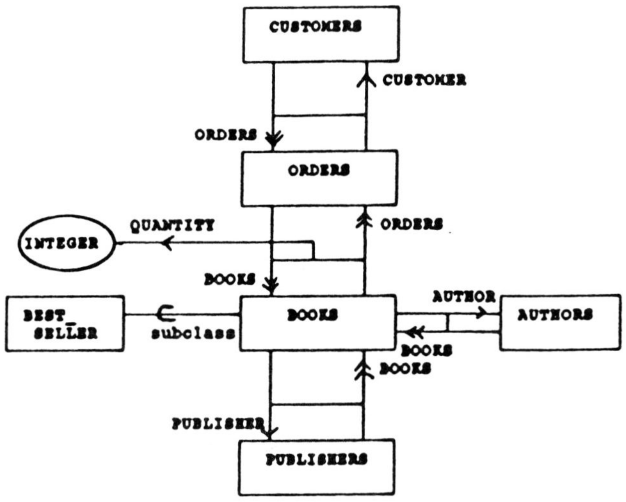
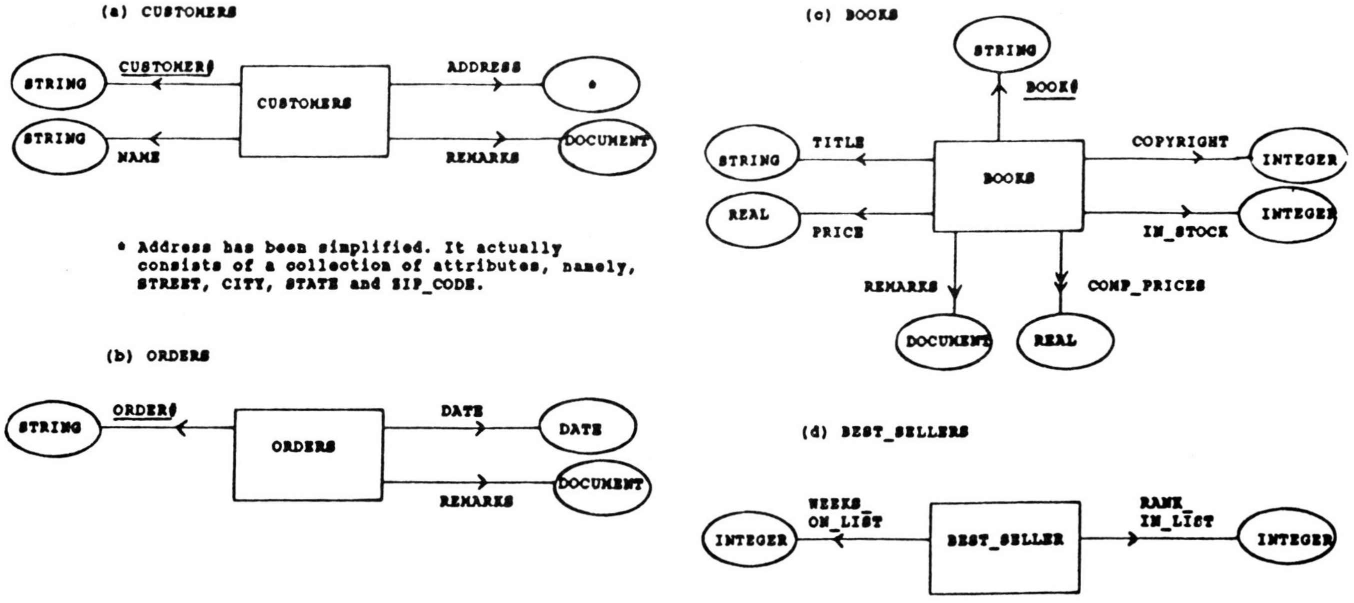


Figure B.2 Entity classes and subclasses with their scalar attributes.


(a) CUSTOMERS
STRING
CUSTOMER#
CUSTOMERS
ADDRESS
*
STRING
NAME
REMARKS
DOCUMENT
* Address has been simplified. It actually consists of a collection of attributes, namely, STREET, CITY, STATE and ZIP_CODE.
(b) ORDERS
STRING
ORDER#
ORDERS
DATE
DATE
REMARKS
DOCUMENT
(c) BOOKS
STRING
BOOK#
TITLE
STRING
BOOKS
COPYRIGHT
INTEGER
REAL
PRICE
IN_STOCK
INTEGER
REMARKS
COMP_PRICES
DOCUMENT
REAL
(d) BEST_SELLERS
INTEGER
WEEKS_ON_LIST
BEST_SELLER
RANK_IN_LIST
INTEGER