Teaching Database Management System Use in a Library School Curriculum

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Database management systems are in widespread use as efficient means for managing information in a computer. This paper describes how the use of such systems is being taught to students at the School of Library and Information Studies, University of California, Berkeley. It discusses some of the concepts of database systems and presents an instructional data base used by students in the course.

Introduction

Database management systems (DBMS) are computer programs designed to manage the storage, maintenance, and retrieval of information from a computer system. Their use in many different kinds of computing environments is widespread because they perform the essential functions that almost every data processing application requires. In addition, they provide significant advantages over previous file management techniques.

This paper discusses how the use of database management systems has been taught to graduate students at the School of Library and Information Studies, University of California, Berkeley over the past seven years. It presents examples of the instructional database used in the course, the course outline, and the instructor's experiences with teaching the course.

Database management systems evolved when individuals realized that they were continuously performing the same set of functions on files of data: creating, maintaining, and querying. It was apparent that a common set of programs to perform these functions would be extremely useful. With this came the realization that the physical contents of a record in a file were constantly changing, either because of additions or deletions of the fields or because of changes in the meaning of codes used in a field.

Thus emerged the concept of data independence—that is, that the way the data are physically stored in a computer system should be separated from the way a programmer logically views or accesses the data. One of the most important features of database management systems is this provision for data independence. For the most part, the way the data is physically stored on a disk is almost no concern of the application programmer. When the programmer needs a record or field of a record to process, a request is made to the system, and the information is supplied.

The implementation of data independence concepts had an additional by-product, namely, the possibility that one common physical database could be accessed by more than one application program, and that each application could have a different logical view of the data. The terminology used in the literature is not consistent, but in some vocabularies, the concept is referred to as having one schema that logically describes the entire database, and having a number of subschemas. Each subschema is a representation of that part of the entire logical data base a particular application program will access.

The concept of different logical views of the data leads to another important benefit of using database management systems, data security. The application program obtains a record by a request to the DBMS. The subschema for the application is retrieved by the DBMS, and a mapping is made between the subschema's view of the data and the schema's representation of the entire database. Then, a data access path is established to allow the physical data to be retrieved. Data security is enforced in several ways. The application can only retrieve fields of data that are specified in the subschema. Limitations are placed on particular fields for retrieval only, updating only, or a combination of the two. Further, the application program has no ability to directly access the physical data; all access takes place through the control of the database management system.

The most important aspect of database management systems, for users of the data, is the powerful query language facilities that are available on almost all the systems. These languages vary in complexity, but even in their most primitive form, they allow a user with a few hours of train-

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ing to develop relatively complex queries. Many systems have statistical summary commands available to the user (for example, mean, standard deviation), as well as commands that allow results to be graphically and tabularly displayed. Enhancements to the query languages have appeared recently that perform simple to complex inference-making by the system, in response to the user's query.

Approaches to Teaching DBMS

Two approaches can be taken to teaching database management systems. The first is to teach students the theory of database systems so they can write programs and conduct research on DBMS. For example, at Berkeley, there is an important research group in the Computer Sciences Department that has been working for a number of years on relational database systems.

At the School of Library and Information Studies, students are taught the theoretical concepts of data models, query processing, and physical file organization. Primarily, however, the emphasis is on how to build and manipulate their own files of information using a DBMS, and how to manage a database environment.

There are a number of reasons for this approach. The school's major emphasis is one of a professional school training graduate students at the master's degree level for positions in managing and organizing information. Database management systems are simply computer programs that facilitate the managing and organizing process in a computer, rather than manually. Students should have the ability to use these programs just as well as they use traditional manual organizational methods.

Many graduate students at the school expect that one of their major functions as professionals will be to act as intermediaries between users needing information and the information itself. They come to the school with strong interpersonal skills and an orientation toward helping information users. After learning the use of database management systems, as well as the traditional library skills of cataloging, classification, and reference, they are in a position to help manage a database system.

Course Structure

The course offered in the school consists of two parts: lectures of three hours a week for fifteen weeks and practical assignments using database management systems. The lectures cover a number of topics:

Introduction to database concepts

This section provides general definitions of database concepts. It then discusses the three principal models that serve as a basis for logically organizing data in a DBMS: the relational, hierarchical, and network models.* In a relational model, the data is organized into relations (tables) that consist of tuples (rows or records) and domains (columns or fields). When data is organized relationally, no set way of accessing the data is imposed when the data is initially stored in the relations.

A hierarchical model, as the name implies, requires that data be organized in a hierarchy. In this model, there is usually one access point. In a bibliographic database the hierarchy might be structured by the author field of the bibliographic record. To find a particular record, the author field is used to locate the record in the hierarchy of all records.

A network model does not require a hierarchy between individual records. In a bibliographic database, the network organization would form a chain with all author names logically linked to one another. Other chains might be formed with titles, publishers, and the like.

The concepts of schemas and subschemas are also presented, along with a discussion of data independence.

Physical file organization techniques

This section introduces the concepts of sequential, direct access, index sequential and b-tree file organization schemes. (See Teorey and Fry [17], and Wiederhold [19], for a review of these methods). Once the students have a general idea of the physical organization methods, an overview of the process of retrieving records (from logical request to physical retrieval) is presented. After students understand that data access paths are not permanent, the concepts of when a path should be established, and how permanent it should be (i.e., when binding should occur), are introduced.

Design of databases

One of the most difficult tasks in the course is to teach students how to perform the logical design of a database. In order to convey the design process, cases are presented to illustrate design concepts [1], the problems of normalization of databases are discussed [8], and time is spent with each student reviewing his or her own database design.

The role of a database administrator (DBA)

Students who have taken the course have accepted positions as data base designers, as individuals who act as intermediaries between a technical database support group and the end users, as instructors in database management systems, or as managers of database operations. This section of the course discusses the role that a manager of a database system plays in an organization, and the functions that the person performs [1], [18]. The section is particularly relevant to our students since this is a major activity they perform.

The next topics that are covered in the course deal with each of the three data models, and with specific commercially available database management systems that the students use to organize their data.

*Data [3] provides a good summary of the models.

Relational database systems

In this section of the course, the concepts of relational algebra and relational calculus are presented as a foundation for understanding query languages [3]. The lectures then discuss the INGRES system as an example of a relational DBMS.* Students learn the QUEL query language (which is part of the INGRES system), perform an INGRES tutorial, and answer queries using a relational database that the instructor has set up. As one of their assignments, students set up a database of their own choosing on the INGRES system. After learning about INGRES, the lectures then introduce other relational systems such as QBE (Query By Example) [5].

Hierarchical database systems

In a manner parallel to the discussion of relational systems, the lectures present a discussion of hierarchical systems. The database management system that is used in this section to illustrate the concepts is FOCUS [4]. Once again, the students learn to query the instructor's database, and then build their own database using FOCUS. They also learn the FOCUS query language and report writer as examples of powerful nonprocedural languages.

After the students have had some exposure to FOCUS, some of the concepts of IBM's Information Management System (IMS) are introduced to give an idea of its size, complexity, and structure [6].

Network database systems

Time constraints prevent the students having hands-on experience with a network system. Nevertheless, the CODASYL report is presented in lectures, and an example of a CODASYL database system (IDMS) is discussed [3], [13],

Additional topics

A number of other topics are covered in the class. They include discussions of security, accuracy and privacy of databases [11]; data dictionaries [9]; problems of distributed databases and concurrency control; processing of distributed queries; and back-end database machines [12]. The course closes with a presentation of methodologies used in performing comparative evaluation of these systems.

Student Assignments

A major portion of the students' assignments is developed to learning how to use database management systems. Over the years that the course has been taught, a number of database systems have been used. They include INGRES, System 2000, RAMIS, FOCUS, INFOS, INQUIRE, and dBASEII. The students have had demonstrations of QBE, ADABAS, IDMS, and IMS as well. During the last few years, the course has settled on INGRES and FOCUS as the main systems. INGRES began at Berkeley as a research DBMS with a relational data model as its base. It is now marketed commercially, FOCUS is a hierarchical DBMS with a powerful query language and excellent report writing facilities. At Berkeley, INGRES runs on a Digital Equipment Corporation VAX 11/780 under the UNIX operating system. FOCUS runs at Berkeley on an IBM 3081 computer under the CMS operating system.

The database exercises begin with INGRES. The students, if they are not already familiar with it, go through a series of self-paced tutorials to learn about UNIX and one of its text editors [2]. Then they go through another series of self-paced tutorials to learn INGRES [15]. Once they have a basic familiarity with the system, they are given a series of queries to answer from a bibliographic database that the instructor has set up on the INGRES system. (The appendix describes and illustrates the database used in the course, and gives examples of the types of queries the students answer from the database).

In the next exercise, the students pick a body of information that they wish to organize, develop a logical structure for it, gather the data, and create a relational version of their data on the INGRES system. Once the database is set up, they document its structure, and formulate and run their own queries against the database.

As was the case with INGRES, students begin learning about FOCUS by first completing a series of self-paced tutorials to learn about the CMS operating system and one of its text editors [7].

The same database that was set up on INGRES by the instructor is also in place on FOCUS, and the students process the same queries as they did on INGRES, only this time using the FOCUS query language.

No database environment is stable, and one of the things the course deals with is conversion of the student's database from one system (INGRES) to another (FOCUS). This usually results in some reoganization of their databases (and at times some frustration). At Berkeley, the UNIX and CMS systems are linked together by a simple file transfer system. The students reformat their INGRES data into a form suitable for FOCUS, and then transfer the data files between machines. Once the files have been transferred, they build a FOCUS version of their database, document it, and run the same queries against it that they did against the INGRES version.

Course Evaluation

This course began as an attempt to teach graduate library school students how to use database management systems. It has now also evolved into a service course for students in departments such as mechanical engineering, civil engineering, business administration, psychology, and education. Although the orientation of the course is to

*Documentation for the INGRESS system can be found in [14] and [16].

TABLE 1. Selected tuples from the INGRESS BOOK relation.

Accno	Author	Title	Loc	Pubid	Date	Price	Pagin	Ill	Height
a002	gastner, alan, ed.	after deschooling, what?	new york	24	1973	200	x, 162 p.		18
a003	american library association	ala bulletin	chicago	04	jan	300	63 v.	ill.	26
b005	barzun, jacques	the american university : how it runs, w	new york	24	1970	500	xii, 319 p.		20
b006	balderston, frederick e.	managing today!s university	san francisco	27	1975	600	xvi, 307 p.		24
b007	barzun, jacques	teacher in america	garden city	18	1954	700	280 p.		18
b008	barzun, jacques	the house of intellect	new york	24	1961	800	viii, 271 p.		21
b009	benson, charles s.	implementing the learning society	san francisco	27	1974	900	xvii, 147 p.		24
b010	bell, daniel	the coming of post-industrial society :	new york	09	1976	1000	xxvii, 507 p.		21
b012	berg, ivar	education and jobs : the great training	boston	10	1971	1200	xx, 200 p.		21
b013	bird, caroline	the case against college	new york	08	1975	1300	xii, 308 p.		18
b014	beveridge, william i.	the art of scientific investigation	new york	58	1957	1400	xiv, 239 p.		18
b015	haskins, james	black manifesto for education	new york	60	1974	1500	xvi, 201p.		21
b016	bissell, claude t.	the strength of the university	toronto	57	1968	1400	vii, 251 p.		21
b018	budig, gene a.	academic quicksand : some trends and iss	lincoln, nebraska	37	1973	1300	74 p.		23
c019	conant, james bryant	slums and suburbs	new york	30	1961	1200	viii, 147 p.		20
c020	morison, robert s.	the contemporary university: u.s.a.	boston	10	1967	1100	xvi, 364 p.		20
:	:	:	:	:	:	:	:	:	:
:	:	:	:	:	:	:	:	:	:
s081	stanford university. study of	the study of graduate education at stanf	stanford	42	1972	1195	x, 323 p.		23
s100	schein, edgar h.	professional education : some new direct	new york	30	1972	600	xiii, 163 p.		24
s101	schneider, franz	students examine their professors : a st	berkeley	22	1939	500	32 p.		22
s102	brown, sanborn c., ed.	scientific manpower	cambridge, mass.	29	1971	400	x, 180 p.		26
t082	anderson, theodore	the teaching of modern languages	paris	53	1955	1095	294 p.		22
t083	tussman, joseph	experiment at berkeley	new york	34	1969	995	ix, 139 p.		21
u084	university of california. all	the future of graduate and professional	s.l.	54	1971	895	78 p.		23
u085	university of california, berk	the berkeley campus and the people of ca	berkeley	55	1974	795	vi, 67 p.		28
u086	university of california	revised academic plan, 1969-1975	berkeley	50	1969	695	vi, 217 p.		23
u087	university of california, berk	education at berkeley : report of the se	berkeley	55	1960	595	xi, 252 p.		21
u088	university of california	communication and society : an interdepa	berkeley	54	1975	495	33 p.		22
v091	van doren, mark	liberal education	boston	10	1972	195	178 p.		20
v092	veysey, laurence r.	the emergence of the american university	chicago	56	1970	95	xiv, 505 p.		21
w093	warshaw, stephen	the trouble in berkeley	berkeley, calif.	17	1965	2795	128 p.	illus.	28
w095	whitehead, alfred north	the aims of education and other essays	new york	31	1949	3500	166 p.		18
w096	washington [state]. state boar	washington!s open door colleges : compar	olympia, wash.	45	1970	0	21 p.		28

Note: The data presented in this table is extracted from a larger database. It is presented to illustrate database concepts, not cataloging concepts.

show the use of these systems for bibliographic applications, the content of the databases the students develop is quite varied. Some examples of the more than 200 student databases include a database designed to help a user select a microcomputer; databases of San Francisco Opera and San Francisco Ballet performances and performers; a database to help a user get from one point to another on a subset of New York Subway System lines; and a database to provide information on an ongoing building construction project.

The emphasis in the construction of the student databases is quality of design rather than quantity of data. Usually, the databases contain less than a hundred records, but that does nothing to mitigate a complex design.

The resources required to operate the course are high, both in terms of time and money. Each time the course is offered, the instructor's databases must be created, and all the procedures and queries checked. Vendors are constantly making changes to their database products, and documentation and procedures that worked during one year or month may not necessarily work during the next.

Besides the three hours of lecture per week, approximately ten hours per week of teaching assistance and instruction time is available for individual student consultations.

The text for the course has changed over the years as the emphasis and the context have changed. Tests used in the past include Date [3], and Martin [10], and Atre [1].

Appendix

The Instructional Database

The bibliographic database that is set up for the students on the database management system is called COOKIE*. The COOKIE database consists of three types of information: bibliographic, library, and publisher. The bibliographic data includes the following elements for each item:

Accession number of the item
Author
Title
Subject headings
Place of publication
Publisher identification number
Date of publication
Price
Pagination
Illustration statement
Height
Call number
Number of copies owned

*COOKIE is not an acronym. It is derived from the author's strong interest in the chocolate chip variety.

The library data includes:

Library identification number
Library name
Street address
City
State
Zip code
Phone number
Opening and closing hours of the library by day of the week

The publisher data includes:

Publisher identification number
Publisher name
Street address
City
State
Zip code
Phone number
Shipping time code

INGRES Implementation of the COOKIE Database

There are many different ways in which the data described above can be organized to fit a particular data model. This section illustrates one approach using a rela-

TABLE 2. Selected tuples from the INGRES COLLECTION relation.

Accno	Libid	Call Number	Copies
a002	01	lc1390	2
a002	02	370.1	1
a002	03	lc5158	2
a002	04	371.1	2
a002	06	370.1	1
a002	07	lc1393	1
a002	08	370.11	1
a002	09	lc1390	1
a002	10	370	0
b008	06	370.11	1
b009	07	lb3640	2
b010	08	370.12	1
b011	09	lb125	1
b012	10	370.21	1
b013	11	lb3395	1
b015	13	lb3095	1
b016	14	370.5	1
b017	01	lb1051	1
k060	12	370.999	1
k061	01	lc5205	1
k062	13	lc6691	1
k063	14	370	1
m064	09	la99999	1
m065	04	371.1	1
m066	13	lb51	1
m067	08	370.1	1
p069	12	370	1
p070	02	370	1
p071	07	lb1025	1
p072	05	lb1050	1

TABLE 3. INGRES LIBRARY relation.

Libid	Lib	Address	City	State	Zip	Phone
01	doe library		berkeley	ca	94720	4156423403
02	moffitt library		berkeley	ca	94720	4156425070
03	education-psychology library	2600 tolman hall	berkeley	ca	94720	4156424208
04	berkeley public library - main branch	shattuck ave. & kittredge	berkeley	ca	94704	4156446100
05	berkeley public library - claremont branch	2940 benvenue ave.	berkeley	ca	94705	4156446880
06	oakland public library	125 14th street	oakland	ca	94612	4152733134
07	san francisco public library - main branch	civic center	san francisco	ca	94102	4155583191
08	san francisco public library - chinatown b	1135 powell	san francisco	ca	94108	4159896770
09	mechanics institute library	57 post street	san francisco	ca	94104	4154211750
10	stanford university libraries		stanford	ca	94305	4154971811
11	san jose state university library	125 s 7th street	san jose	ca	95112	4082273373
12	state of california library	9th & capitol mall	sacramento	ca	95814	9164454374
13	college of marin library		kentfield	ca	94904	4154859470
14	library of congress	1st bet. e. capitol & ind	washington	dc	20540	7034265000

Mop	Mcl	Tuop	Tucl	Wop	Wcl	Thop	Thcl	Fop	Fcl	Satop	Satcl	Sunop	Suncl
800	2000	800	2000	800	2000	800	2000	800	1700	1300	1700	1300	2000
800	2200	800	2200	800	2200	800	2200	800	1700	900	1700	1300	2200
800	2200	800	2200	800	2200	800	2200	800	1800	1300	1700	0	0
800	2400	800	2400	800	2400	800	2400	800	1800	1000	1800	1000	2400
900	1700	900	1700	900	1700	900	1700	900	1700	0	0	0	0
900	1900	900	1900	900	1900	900	1900	900	1700	1000	1700	1200	1700
900	1900	1000	1900	900	1700	900	2000	900	1700	1100	1700	1300	1800
900	2000	900	2000	900	2000	900	2000	900	1700	1200	1700	1300	1700
900	2100	900	2100	900	2100	900	2100	900	1700	1300	1700	1300	1700
900	2100	900	2100	900	2100	900	2100	900	1800	900	1800	0	0
900	2100	900	2100	900	2100	900	2100	900	1800	900	1800	1300	1700
1000	1600	1000	1600	1000	1600	1000	1600	1000	1500	0	0	0	0
1000	1600	1000	1600	1000	1700	1000	1700	1000	1700	0	0	0	0
1000	2100	1000	2100	1000	2100	1000	2100	1000	1800	1000	1800	0	0

Note: Each tuple (row) in the LIBRARY relation consists of 21 domains (columns). The relation is broken into two parts in this table for printing convenience.

tional model, and illustrates the approach with some of the actual data from the COOKIE database.*

The logical organization of the data does not necessarily conform to the way the data are physically organized, and Tables 1 through 6 illustrate this. The BOOK relation in Table 1 contains most of the bibliographic data. Note that in this relation the publisher name has been replaced with a publisher number (Pubid). Information about the library that held the item, the call number of the item, and the number of copies has been moved to the COLLECTION relation of Table 2. The COLLECTION relation is what is termed a linking relation. It provides a link between a particular item in the BOOK relation and a particular library that holds the item (through the library identification [Libid] number). The COLLECTION relation allows for the possibility that a book may be in different libraries with different call numbers.

The LIBRARY relation of Table 3 and the PUBLISHER relation of Table 4 are relatively straightforward. They simply contain information about the library and publisher. The information in the PUBLISHER relation is linked to the BOOK relation by the publisher number (Pubid) in the BOOK relation and the publisher number in the PUBLISHER relation.

Tables 5 and 6 give subject information about the books in Table 1. Table 5 lists the subject headings themselves, and Table 6 links the headings to a particular book. Table 6 shows, for example, that subject heading (Subcode) 02 has been assigned to documents b015 and f047. It also shows that document s080 has both subject heading 19 and 20 assigned to it.

Sample Queries for the Instructional Database

Some of the questions students are asked to answer using the COOKIE database on the INGRES and FOCUS database management systems are given below.†

1. What is the phone number of the San Francisco Public Library (the main branch)?
2. What is the title of the most expensive book in the database?
3. Where would you write to purchase a copy of *Black Manifesto for Education*?

TABLE 4. Selected tuples from the INGRES PUBLISHER relation.

Pubid	Name	Address	City	State	Zip	Phone	Ship
01	allyn and bacon inc.		rockleigh	nj	07647	2016432652	20
02	american academy of arts and s	165 allandale	jamaica	ma		3175222400	0
05	arlington house pubs.	165 hugenot st.	new rochelle	ny	10801	2126549876	14
06	atherton press inc.	1841 broadway	new york	ny		2125862118	19
07	ballantine books inc. div. of		westminster	md	21157	3012567456	120
08	bantam books inc.	414 e. golf rd.	des plains		60016	1234567890	14
09	basic books inc.	10 e. 53rd st.	new york	ny	10022	2128455759	30
10	beacon press inc.	25 beacon st.	boston	ma	02108	6177239625	30
12	change magazine	nbw tower	new rochelle	ny	10801	2126432687	15
15	david mckay company inc.	750 3rd ave.	new york	ny	10017		0
16	dell publishing co. inc.	1 dag hammarskjold p	new york	ny	10017		21
18	doubleday and company inc.	501 franklin ave.	garden city	ny	11530		25
21	fawcett world library	1515 broadway	new york	ny	10036	2128693000	16
:	:	:	:	:	:	:	:
:	:	:	:	:	:	:	:
42	stanford university press		stanford	ca	94305		7
46	the brookings institution		washington	dc			0
50	the regents of the university		berkeley	ca	94720		10
51	the western interstate commiss		boulder	co			90
52	u. s. office of education	400 maryland ave sw	washington	dc		7032458707	30
53	unesco	9 pl fontenoy 7e	paris	fr		5665757	60
54	university of california		berkeley	ca	94720		0
55	university of california press	2223 fulton st.	berkeley	ca	94720	4156424247	10
56	university of chicago press	11030 s. langley ave	chicago	il	60628		30
57	university of toronto press	33 e. tupper st.	buffalo	ny	14208		35
58	vintage books	201 e. 50	new york	ny		2127512600	21
59	w. w. norton & co. inc.	5 12 fifth ave.	new york	ny	10036		0
60	william morrow	105 madison ave.	new york	ny		2128893050	25

Note: The data presented in this table is extracted from a larger database. The accuracy of the data has not been verified for a number of years, since it is used to illustrate concepts, not specific facts.

*Readers interested in the implementation of the COOKIE database on the FOCUS system may contact the author for further details.

†Tables 1-6 contain extracts of the COOKIE database and as such do not contain all the information needed to answer the queries given here.

TABLE 5. INGRES subject headings relation.

Subcode	Subject
01	adult education
02	afro-american education
03	college teachers - salaries
04	college teachers - tenure
05	community colleges
06	education - aims and objectives
07	education - philosophy
08	education - u.s.
09	education and employment
10	education, higher
11	educational accountability
12	educational innovations
13	educational law and legislation
14	educational planning
15	educational sociology
16	information services
17	intellectuals
18	professional education
19	school management and finance
20	sex discrimination
21	social change
22	student movements
23	teaching
24	universities and colleges
25	university of california
26	vocational education
27	women - social conditions

TABLE 6. Selected tuples from the INGRES subject assignments relation.

Subcode	Accno
01	f046
01	l062
02	b015
02	f047
03	f044
04	c025
05	c029
05	c030
05	k061
05	w096
06	a002
06	u084
07	h051
10	b009
14	u084
15	a002
15	c019
18	s100
18	s102
19	f038
19	r073
19	s080
20	g048
20	s080
21	b010
25	t083
25	u089
25	w093
26	a004
26	r075
27	c027

Note: The data presented in this table is extracted from a larger database.

4. Where is the closest available copy of any book by Jacques Barzun?
5. A patron needs a copy of *Slums and Suburbs*. What do you recommend?
6. What is the total replacement cost of all the material in the Moffit Undergraduate Library at the University of California, Berkeley?
7. What are the author and title of books in the San Francisco Public Library that cost over $10.00?
8. What is the total cost of books purchased from New York publishers by the San Francisco Public Library?
9. Produce mailing labels, sorted by zip code, for all publishers in the state of New York.
10. Produce a report of the purchase price and replacement cost of all books for each library. Replacement cost of a book varies by the publication date of the book: (a) books published before 1960 will cost double the publication price, (b) books published from 1960 to 1969 will cost 50% more than the publication price, (c) books published from 1970 to 1979 will cost 25% more than publication price, and (d) books published after 1979 will cost the same as the purchase price to replace.
11. Produce a table of the number of titles in each library that are greater than 23 cm. high. Include column and row totals.

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