CGTM 60
February 1969

# FORMULARIES-- PROGRAM CONTROLLED PRIVACY IN LARGE DATA BASES

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## ABSTRACT

This working paper describes a method of separating, in large computer data bases, the function of data addressing from the function of access control. This method is based on sets of access control procedures called formularies. The decision on whether a user can read, write, update, etc., data is controlled by programs (not merely bits or tables of data) which are completely independent of the contents or location of raw data in the data base. This decision is made at data access time, not at file creation time as has generally been the case in the past. Indeed, the model presented does not make use of the concept of "files", though a specific interpretation of the model may do so. Access control is not restricted to the file level or the record level, although the model permits either of these. If desired, however, access can be controlled at arbitrarily lower levels, even at the bit level. Each element of raw data need appear only once, thus allowing considerable savings in memory and in maintenance effort over previous file-oriented systems.

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## 1. Introduction

This working paper describes a method of separating, in large computer data bases, the function of data addressing from the function of access control. It presents a model in which the decision on whether a user can read, write, update, etc., data is controlled by programs (not merely bits or tables of data) which are completely independent of the contents or location of raw data in the data base. This decision is made at data access time, not at file creation time as has generally been the case in the past. Indeed, the model presented does not make use of the concept of "files", though a specific interpretation of the model may do so. Access control is not restricted to the file level or the record level, although the model permits either of these. If desired, however, access can be controlled at arbitrarily lower levels, even at the bit level. Each element of raw data need appear only once, thus allowing considerable savings in memory and in maintenance effort over previous file-oriented systems.

Specifically not considered in the model are privacy problems associated with communication lines, electromagnetic radiation monitoring, physical security, wiretapping, personnel, or administrative procedures. Cryptographic methods are not dealt with in any detail, though provision is made for inclusion of encrypting and decrypting operations in any particular interpretation of the model.

Specific interpretations of the model can be implemented on a standard, general-purpose computer with no special time-sharing or other hardware. The only provisio is that all requests to access the data base must be guaranteed to pass through the data base system.

## 2. The Formulary Method of Access Control -- General

We now describe the "formulary" method of access control. This method separates the function of data addressing from the function of access control. Both functions proceed independently, as shown in the programs of Appendix A. The decision on whether a user can perform operations such as read, write, lock, etc., on each datum is controlled by programs (not bits or tables) which are completely independent of the contents or location of raw data in the system. Access control is not restricted to the file level or the record level, although the method permits either of these. Access to individual related datums, which may have logical addresses very close to each other, can be controlled individually. For example, a salary figure might be released only without any identification of an employee.

The decision to grant or deny access is made at datum request time, rather than at file make-up time, as has generally been the case in previous systems. This, together with the fact that the decision is made by a program (not by a scan of bits or a table), allows more flexible control of access and more efficient storage management. Data-dependent, terminal-dependent, time-dependent, and user response-dependent decisions can now be made dynamically at data request time, in contrast to the predetermined decisions made in previous systems, which are, in fact, subsumed by the formulary method.

The basic idea behind the formulary method is that a user, a terminal, a formulary (defined below), and (sometimes) a data set, must be all linked together, or attached, in order for a user to perform information storage and retrieval operations. At the time the user requests use of the data base system, this linkage is effected, but only if the combination of user, terminal, formulary, and (sometimes) data set is allowed. The general linking process is described in Section 4.4, "The Attachment Process--The Method of Linking a Formulary to a User and Terminal".

IT IS ASSUMED THAT ENOUGH VIRTUAL ADDRESSING CAPACITY IS AVAILABLE TO HANDLE THE ENTIRE DATA BASE. VIRTUAL ADDRESSES ARE MAPPED INTO THE PHYSICAL CORE MEMORY LOCATIONS, DISC TRACKS, LOW-USAGE MAGNETIC TAPES, ETC., BY HARDWARE AND BY THE GET, PUT, GETANDLOCK, AND PUTANDLOCK MACROS (SEE APPENDIX B) FOR A PARTICULAR IMPLEMENTATION.

## 3. Formularies--What They Are

This section defines formularies, the sets of procedures which are the backbone of the access control method being presented. The next section gives examples of the use of formularies in a typical system.

A formulary is defined as a set of procedures, described below, which control access to information in a data base. These procedures are invoked whenever access to data is requested. They perform various functions in the storage and retrieval of information.

Different users will want different algorithms to carry out these functions. For example, some users will be using data which is inaccessible to others; the name of a particular data element may be specified in different ways by different users; some users will manipulate data structures -- such as trees, lists, sparse files, ring structures, arrays, etc. -- which are accessed by algorithms specifically designed for these structures. Depending on how he wishes to name, access, and control access to elements of the data base, each user will be attached to a formulary appropriate to his own needs.

The procedures of a formulary are called INTNAME, VIRTUAL, CONTROL, SCRAMBLE, and UNSCRAMBLE. In order to describe these procedures, we must first define some terms.

## 3.1. Definitions and Notation

The internal name of a datum is its logical address (with respect to the structure of the data base). The internal name of a datum does not change during continuous system operation.

Examples:

A. A tree name such as 5.7.3.2 which denotes field 2 of branch 3 of branch 7 of branch 5 in the data base.

B. Associative memory identifiers such as (14,273,34), where 14 represents the 14th attribute, 273 represents the 273rd object, and 34 represents the 34th value in a memory similar to the one described in (Rovner and Feldman 1968).

A natural language datum description describes a datum in terms of the user, as opposed to terms of the system.

Example:

(1) Stanford.Cowell.Payroll.Doe.Salary

The above natural language datum description represents the salary field of record Doe of file Payroll of Department File Cowell of Master File Stanford. The internal name corresponding to it might be (for example)

3.67.2.3.23

A User Control Block, or UCB, is space in primary (core) storage allocated during the attachment process (described in Section 4.4). It contains the user identification, terminal identification, and the virtual addresses of the INTNAME, VIRTUAL, CONTROL, SCRAMBLE, and UNSCRAMBLE procedures of the formulary the user is linked to. A data set name may also be included, for efficiency reasons.

The virtual addresses are kept in primary storage in the UCB since a formulary, once linked to a user and terminal, will probably be (oft-)used very shortly. The first reference to any of these addresses (indirectly through the UCB) will trigger some appropriate action (e.g., a page fault on some computers) to get the proper program into primary storage (if it is not there already). It will then presumably stay there as long as it is useful enough to merit keeping in high-speed memory. The virtual addresses of procedures of a formulary cannot change while they are contained in any UCB. This constraint is easy to enforce using the CONTROL procedure (see Section 3.2.3) which controls operations on any datums, including formularies.

In many instances, the user will be performing many operations on the same data set. When this is the case, it is both unnatural and inconvenient to (re-)specify the data set on each operation. The system eliminates the need for the user to do this by accepting a data set name D once, during the attachment process, and saving it in the UCB. As each request to access data is received by the system, D is concatenated with the partial natural language datum description of the request to form the complete natural language datum description, which is then sent to INTNAME to be mapped into an internal name.

## 3.2. Procedures of a Formulary

In this section, we describe the procedures of a formulary. These procedures determine the accessibility, addressing, structure, and interrelationships of data in the data base dynamically, at data request time. They can be arbitrarily complex. In contrast, earlier systems usually made only table-driven static determinations, prespecified at file makeup time. By use of the formulary method, these advantages are gained:

(1) flexibility and changeability of data base organization to reflect current needs

(2) capability to perform access control at request time as well as at file make-up time

(3) more efficient use of storage

Each procedure of a formulary should, if possible, run from (effective) execute-only memory, which is alterable only under administrative control. The integrity of the system depends on the integrity of the formularies and therefore the procedures of all formularies should be written by "system" programmers and audited for program errors, hidden "trap doors", etc., before being inserted into the (effective) execute-only memory under administrative control. Failure to do this may result in the compromising of sensitive data, since an unscrupulous programmer of a formulary could cause the formulary to "leak" sensitive information to himself or to his agents.

If a user who is not a "system" programmer does not wish to trust the confidentiality of his data to a procedure of a formulary written by someone else (a "system" programmer), he may construct his own procedures for his own formulary. The system will permit this formulary only to access data in specific data sets chosen by that user, and thus insure that a user-written procedure does not allow compromise of the data of other users. The system can do this since all formulary building must be done using the program FORMULARYBUILDER.

Each formulary has five procedures: INTNAME, VIRTUAL, CONTROL, SCRAMBLE, and UNSCRAMBLE. We now describe each of these in turn.

### 3.2.1. INTNAME

INTNAME translates a natural language datum description into an internal name, providing a bridge between the user's representation of the data base and the system's representation. INTNAME is an integer procedure with two parameters, FIELD and ANS. The natural language datum description is given in FIELD. The internal name is left in ANS. INTNAME will nearly always be table-driven. It returns

1 on normal exit

2 if it cannot translate FIELD (probably because of an unknown field name given it on input)

### 3.2.2. VIRTUAL

VIRTUAL translates an internal name into the virtual address of the corresponding datum. VIRTUAL is an integer procedure with three parameters, INAME, ANS, and OTHER. INAME contains the internal name to be translated. The virtual address is returned in ANS. OTHER contains sometimes valuable "other information" whose use is described fully in Section 3.2.3, "Control". VIRTUAL returns

1 on normal exit

2 on error exit

REMEMBER, IT IS ASSUMED THAT ENOUGH VIRTUAL ADDRESSING CAPACITY IS AVAILABLE TO HANDLE THE ENTIRE DATA BASE. VIRTUAL ADDRESSES ARE MAPPED INTO THE PHYSICAL CORE MEMORY LOCATIONS, DISC TRACKS, LOW-USAGE MAGNETIC TAPES, ETC., BY HARDWARE AND BY THE GET, PUT, GETANDLOCK, AND PUTANDLOCK MACROS.

### 3.2.3. CONTROL

CONTROL decides whether a user at his terminal is allowed to perform the operation he requests (READ, WRITE, LOCK, etc.) on the particular datum he has specified. CONTROL may consider and/or converse with the requesting user and/or terminal in order to arrive at a decision. CONTROL also checks for correct data set in the case of a formulary built by a person who is not a "system" programmer (see Section 3.2).

CONTROL is a procedure with two input parameters which returns a list as its output. The two input parameters are

(1) the internal name of the datum

(2) the operation the user desires to perform

The output list has two elements. The first element is

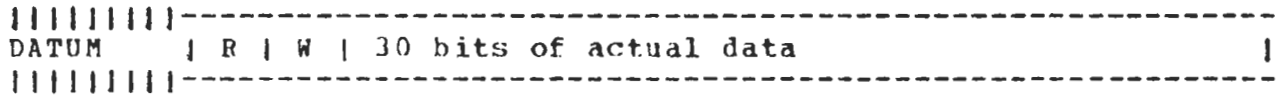
1 if access is allowed, and

2 if access is not allowed.

The second element contains "other information".

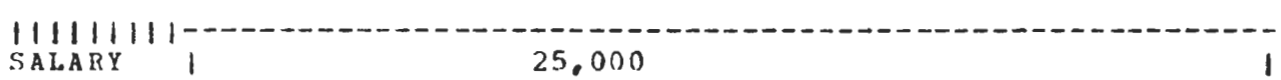
CONTROL returns "other information" as well as a "yes or no answer" for the following reason. In some specific systems, data elements may contain their own access control information. Consider two examples:

Example 1.




If bit R is on, DATUM is readable.
If bit W is on, DATUM is writeable.

Example 2.




Reading or writing of salaries over $25,000 is not to be done in any case. CONTROL must inspect the SALARY cell before it can do further capability checking and eventually return 1 or 0 as the first element of its output list.

In systems of this type, CONTROL might often duplicate VIRTUAL's function of transforming the internal name of a datum into that datum's virtual address. To achieve greater efficiency, therefore, CONTROL can (when appropriate) return the datum's virtual address as "other information". VIRTUAL, which is called after CONTROL (see ACCESS in Appendix A), can then examine this "other information". If a virtual address has been put there by CONTROL, VIRTUAL will not duplicate the possibly laborious determination of the datum's virtual address, since this has already been done. VIRTUAL will merely pluck the address out of the "other information" and pass it back.

### 3.2.4. SCRAMBLE

SCRAMBLE is a scrambling procedure which transforms raw data into encrypted form. (In some specific systems, SCRAMBLE may of course be null.) SCRAMBLE has two input parameters:

(1) the virtual address of the datum to be scrambled

(2) the length of the datum to be scrambled

SCRAMBLE returns a three-element list, the elements of which are

(1) a completion code (1 if normal completion)

(2) the virtual address of the scrambled datum

(3) the length of the scrambled datum

### 3.2.5. UNSCRAMBLE

UNSCRAMBLE is an unscrambling procedure which transforms encrypted data into raw form. (In some specific systems, UNSCRAMBLE may of course be null.) UNSCRAMBLE has two input parameters:

(1) the virtual address of the datum to be unscrambled

(2) the length of the datum to be unscrambled

UNSCRAMBLE returns a three-element list, the elements of which are

(1) a completion code (1 if normal completion)

(2) the virtual address of the unscrambled datum

(3) the length of the unscrambled datum

### 3.3. Simultaneous Use of One Formulary by Multiple Users

Note that the same formulary can be used simultaneously by several different users with different access permissions. This is possible because access control is determined by the CONTROL procedure of the attached formulary. This procedure can grant different privileges to different users.

Note also that two formularies can contain the same CONTROL procedure but different INTNAME procedures, thus allowing two different users to use the same data but different natural language descriptions. For example, two formularies might be identical except for the fact that the INTNAME program of the first translated English "field names" into internal names, while the INTNAME program of the second translated French field names into internal names. This ability to use partially or wholly disjoint natural language descriptions for different users is not available currently in any system the author is aware of, though some systems go as far as providing "synonym tables" (Jones 1968).

Different INTNAME programs also allow concealment of the fact that certain information is even in a data base, as illustrated in Figure 1.

Formulary of User 1 is {INTNAME1, VIRTUAL, CONTROL, SCRAMBLE, UNSCRAMBLE}

Formulary of User 2 is {INTNAME2, VIRTUAL, CONTROL, SCRAMBLE, UNSCRAMBLE}

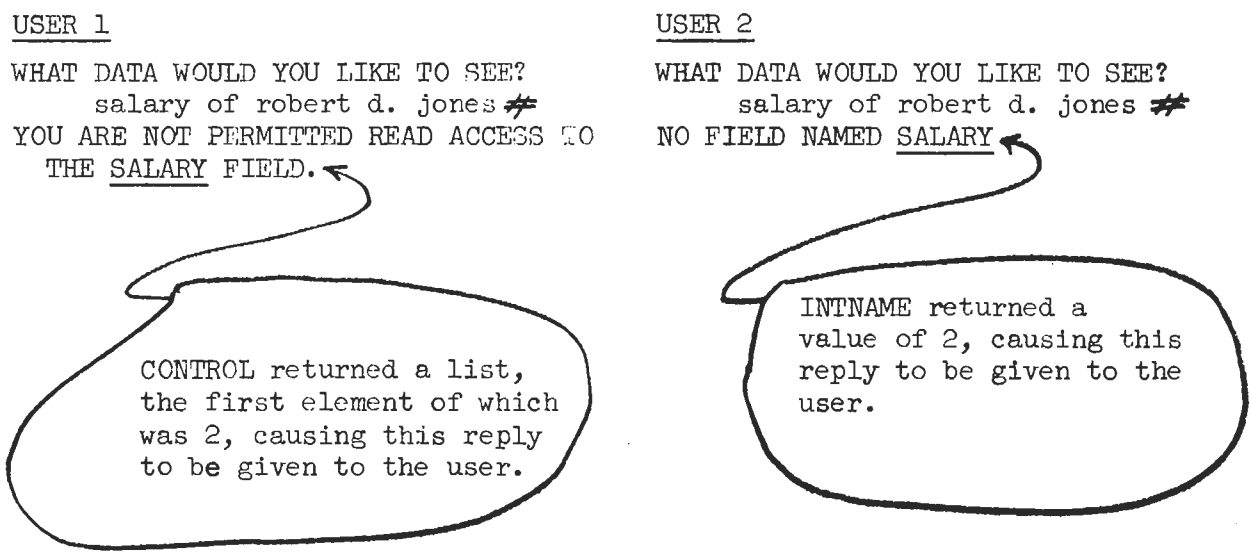



Figure 1. Concealment of the Fact that a Data Base Contains Certain Information

### 3.4. Subdivision of Data Base into Files Not Required

Note that while the concept of a data set (or a "file") MAY be used, the formulary method DOES NOT REQUIRE THIS. This represents a significant departure from previous large-scale data base systems which were nearly all organized with "files" as their major subdivisions. Under the formulary scheme, access to information in a data set is NOT governed by the data set name. Rather, it is governed by the CONTROL program of the attached formulary. Similarly, addressing of data in a data set is governed by the VIRTUAL program and not by the data set name. The data set name, while often useful (for reasons stated in Section 3.1) is not necessary for the system's operation.

## 3.5. Concurrent Requests to Access Data

The problem of two or more concurrent requests for data access necessitates a mechanism to insure that a piece of data may be read and then written with no intervening operations on that data element. This problem has been discussed, and solutions proposed, in (Dijkstra 1965) and (Hsiao 1968) For the purposes of our model, data which must be read and then written with no intervening operations on that data is locked and unlocked at data request time in a manner similar to Hsiao's "blocking" (Hsiao 1968), using a mechanism known as the LOCKSTACK.

### 3.5.1. The LOCKSTACK--Separability of Blocking and Access Control Functions

The locking and unlocking of data to control simultaneous updating is an entirely separate function from the access control function. Access control takes into account privacy considerations only. Locking and unlocking are handled by a separate mechanism, the LOCKSTACK. The LOCKSTACK is a list of doublets maintained by the system and manipulated by the GET, PUT, GETANDLOCK, PUTANDLOCK, UNLOCKREAD, and UNLOCKWRITE primitive operations. Each doublet contains (1) the internal name of a current item, and (2) U, the identification of the user who locked it. No datum represented by a doublet on the LOCKSTACK can be accessed until that doublet is removed from the LOCKSTACK.

## 4. Use of Formularies

We now examine the use of formularies in more detail. A time-sharing system with teletype-like user terminals serves as the framework for our examples. Whenever specific interactive programs are used as examples, the conventions given in Table 1 are followed.

User types in lower case.

System (or user program) types in upper case.

Output messages from time-sharing system are preceded by an exclamation point (!).

The symbol # is used to indicate user depression of the (nonprinting) carriage return and line feed key which terminates user messages and causes them to be sent to the computer.

<BR> indicates a "break character" which, when depressed by the user, causes the output message currently being printed at the user's console to be terminated.

TABLE 1. CONVENTIONS FOR DESCRIPTION OF USER-SYSTEM INTERACTIONS

## 4.1. Building a Formulary

Before a formulary can be attached to a user, terminal, and (possibly) data set, the procedures it contains must be specified. This is done using the system program FORMULARYBUILDER. FORMULARYBUILDER converses with the user who is building a formulary to learn what these procedures are, and then retrieves them from the system library and enters them as a set into a formulary which the user names.

In most cases, the user of FORMULARYBUILDER will be a systems programmer empowered by administrative action to build formularies for the use of all. If this is not the case, FORMULARYBUILDER will require a list of data sets from the (non-system) programmer. Only the information in these data sets will be available to someone using the formulary being built, and then only when other controls (enforced by the CONTROL program) allow.

The general block diagram* of FORMULARYBUILDER is given in Figure 2. The specifics of FORMULARYBUILDER depend on the particular system. An example of the workings of FORMULARYBUILDER for a specific system is given in Fig. 3.

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* An extension to FORMULARYBUILDER which would allow a user to grant capabilities to other users, them to grant capabilities to still other users, etc., has been proposed by Victor Lesser and will be investigated further in the future.

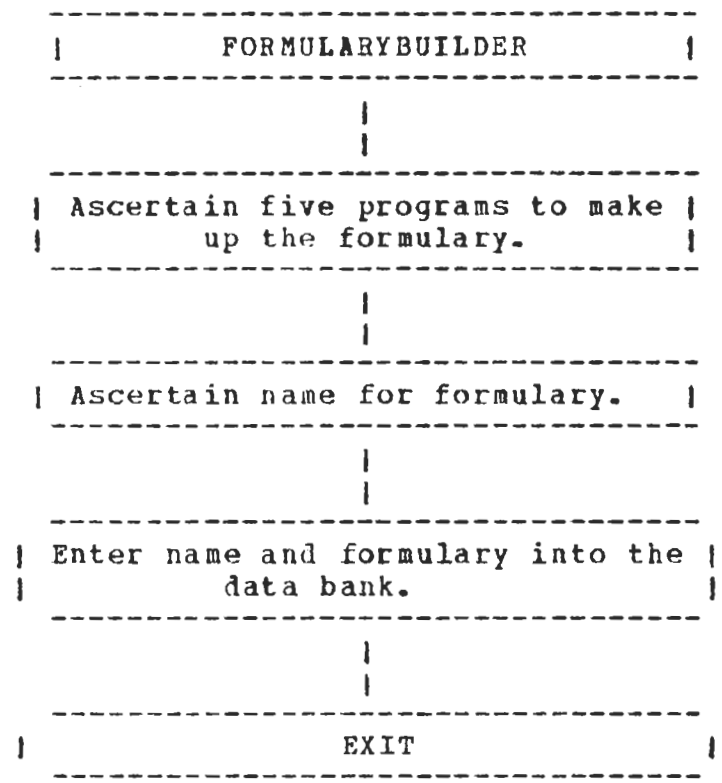
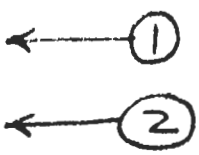



Fig. 2. General Block Diagram of FORMULARYBUILDER Program

```
!WHAT PROGRAM DO YOU WISH TO RUN?
     formularybuilder#
!EXECUTION...
*** FORMULARY BUILDING PROGRAM ***

DO YOU WANT INSTRUCTIONS ON THE USE OF THE FORMULARY BUILDING
  PROGRAM?
     yes #
FORMULARYBUILDER ALLOWS YOU TO DEFINE, OR BUILD, A FORMULARY
  FOR USE AT A LATER TIME.  YOU MUST SPECIFY FIVE PROCEDURES
  TO PERFORM ACCESS CONTROL AND ADDRESSING FUNCTIONS.  WHEN I
  ASK YOU, PLEASE SPECIFY EACH PROCEDURE BY TYPING IN ITS
  NAME (YOU MUST HAVE ALREADY PUT IT ON THE PROCEDURE LIBRARY.)

DO YOU UNDERSTAND THESE INSTRUCTIONS?
     yes#
ALL RIGHT.  PLEASE SPECIFY THE INTNAME PROGRAM.
     public.french.diseases.intname#
THANK YOU.  PLEASE SPECIFY THE VIRTUAL PROGRAM.
     public.standard.virtual#
THANK YOU.  PLEASE SPECIFY THE CONTROL PROGRAM.
     private.cowell.control#
THANK YOU.  PLEASE SPECIFY THE SCRAMBLE PROGRAM.
     private.cowell.scrambler#
THANK YOU.  PLEASE SPECIFY THE UNSCRAMBLE PROGRAM.
     private.cowell.unscrambler#
THANK YOU.  WHAT DO YOU WISH TO NAME THIS FORMULARY?
     health #
IS IT TO BE PUBLIC, OR FOR YOUR OWN USE ONLY?
     public #
ARE YOU A SYSTEM PROGRAMMER AUTHORIZED TO BUILD PUBLIC
  FORMULARIES?
     yes #
...YOUR USER IDENTIFICATION, C. BABBAGE, CHECKS OUT.
...PLEASE RESPOND TO AUTHENTICATION SEQUENCE:
     2547 -- ? 753#
     3940 -- ? 094 #
...AUTHENTICATION VALIDATED.  YOU HAVE DEFINED THE
HEALTH FORMULARY WITH THE FOLLOWING PROCEDURES:

INTNAME:       PUBLIC.STANDARD.INTNAME
VIRTUAL:       PUBLIC.STANDARD.VIRTUAL
CONTROL:       PRIVATE.COWELL.CONTROL
SCRAMBLE:      PRIVATE.COWELL.SCRAMBLER
UNSCRAMBLE:    PRIVATE.COWELL.UNSCRAMBLER

ANY CORRECTIONS?
     no #
FORMULARY HEALTH HAS BEEN ENTERED INTO THE SYSTEM.

    END OF FORMULARY BUILDING PROGRAM

!WHAT PROGRAM DO YOU WISH TO RUN?
```



(1) FORMULARYBUILDER, in order to verify that the user is indeed a system programmer entitled to build public formularies, checks the user identification U (from the UCB) against its list of authorized system programmers.

(2) Then, to double check, it requires the user to pass an authenticity check. In this case, the system supplies a pseudo-random four digit number and the user is supposed to answer with the fourth digit, then the second, then 1 + the first digit (mod 10). A check of this type is necessary to insure that people who are not system programmers do not make available for public use CONTROL programs that could destroy or compromise the sensitive data of other users (see Section 3.2).

Figure 3. Operation of the FORMULARYBUILDER Program in a Specific System

## 4.2. The ACCESS Program

The ACCESS program retrieves information from and stores information into the data base. It uses the INTNAME, VIRTUAL, CONTROL, UNSCRAMBLE, and SCRAMBLE procedures specified in the UCB to carry out these functions. In order for any information storage or retrieval operation to be carried out, the ACCESS program must be invoked. ACCESS has the following parameters:

(1) Natural language datum description

(2) A cell which either contains or will contain the value of the datum specified by (1)

(3) Primitive operation to perform -- READ, WRITE, READANDLOCK, WRITEANDLOCK, UNLOCKREAD, or UNLOCKWRITE.

The primitive operations are specified and an algorithm for the ACCESS program is given in Appendix A, "Algorithms for System Programs".

The user communicates only indirectly with ACCESS. The bridge between the system-oriented ACCESS program and the application-oriented user is provided by the conversational storage and retrieval program, TALK (see Figure 4).

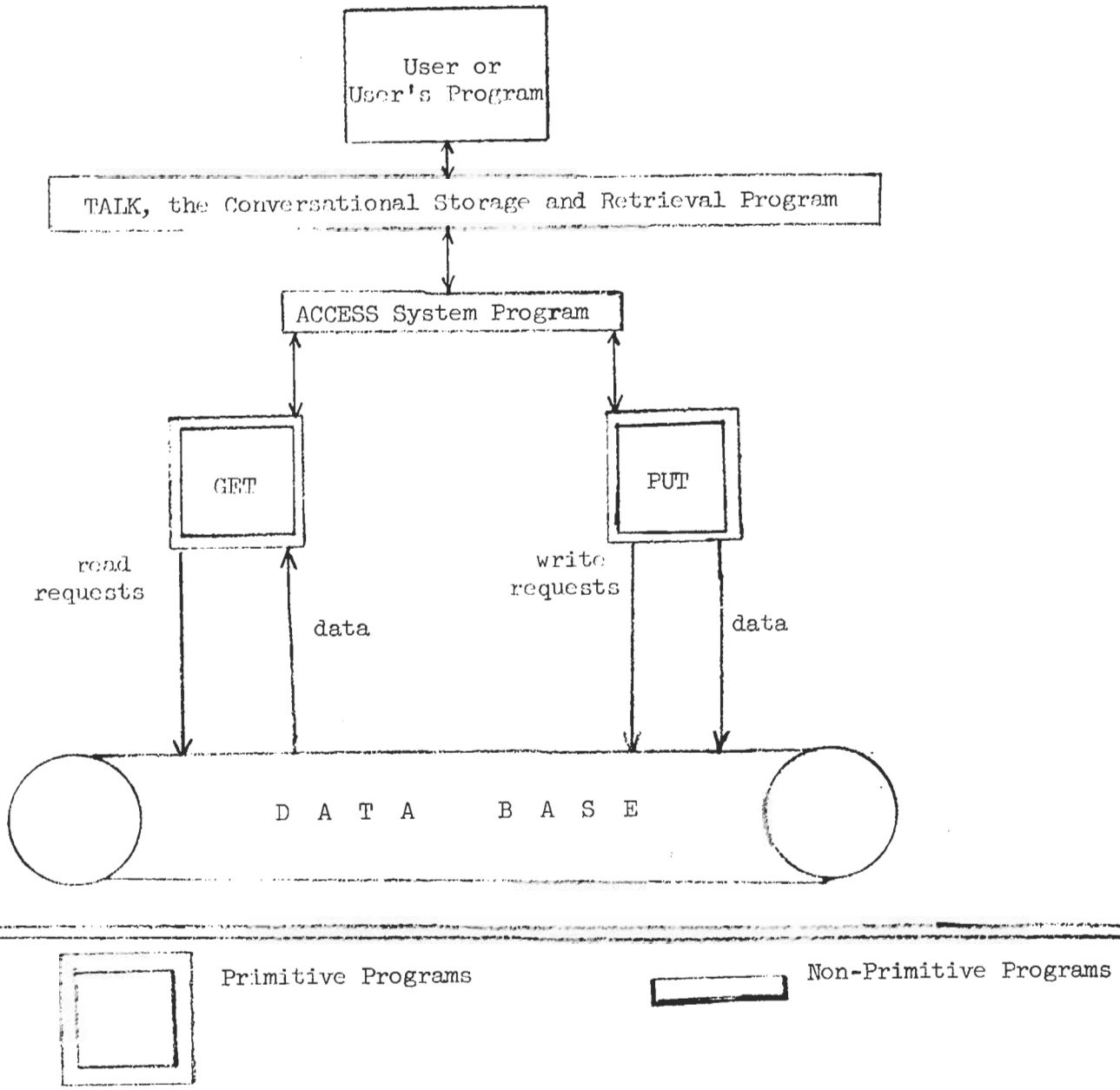



Figure 4. User/Data Base Interface

## 4.3. TALK, The Conversational Storage and Retrieval Program

To access a datum, the user must effectively call upon TALK, the Conversational Storage and Retrieval Program. TALK converses with the user (or the user's program) to obtain (1) a natural language datum description and (2) the operation the user wishes to perform. It then calls the ACCESS program to perform the operation desired. Depending on the particular system, the user may explicitly specify none, one, or both of the above two parameters which TALK sends off to the ACCESS program. Those he does not explicitly specify will be implicitly given values by TALK.

A system may have several TALK programs, depending on the data base structure and on the user's level of expertise. For an experienced user, a bare-bones program which reads parameters from the terminal and passes them along to the access program is sufficient; the novice user will require a much more elaborate TALK program (such as that described in (Kellogg 1968)) to build a bridge between himself and the ACCESS program.

The first task of TALK is to attach a formulary to the user and the terminal. This is discussed in the next section.

4.4. The Attachment Process--The Method of Linking a Formulary to a User and Terminal

In order to allow information storage and retrieval operations on the data base to take place, a user, a terminal, and a formulary which has been previously built using FORMULARYBUILDER must be linked together. A data set may or may not also be linked with the user, terminal, and formulary at this time. This linking, or attaching process is done in the following manner.

The user initially is given the default UCB by TALK. This default UCB contains a user identification U and a terminal identification T which TALK has obtained either directly from the time-sharing system in which the information storage and retrieval subsystem is imbedded, or from conversations with the user and/or with the terminal. TALK, in addition to storing U and T in the default UCB, may also store a data set name D there.

Moreover, the default UCB contains pointers to procedures of the system formulary. This formulary, like all other formularies, contains INTNAME, VIRTUAL, CONTROL, SCRAMBLE, and UNSCRAMBLE procedures. For the system formulary, they act as follows:

INTNAME — INTNAME takes a natural language datum description (in this case, a natural language formulary description) from TALK and transforms it into the internal name of a formulary. This is possible since formularies are stored as datums in the data base.

Example: Calling INTNAME("MEDICAL",ANS) might store "1.14", the internal name for the medical formulary, in ANS.

CONTROL — CONTROL takes the internal name representing the formulary and decides whether user U at terminal T (U and T are in the UCB) is allowed read access to the formulary represented by the internal name.

Example: CONTROL("1.14","GET")=(1," ")

VIRTUAL — VIRTUAL takes the internal name representing the formulary and returns the virtual address

of the first word of the (five-word) formulary

SCRAMBLE No operation.

UNSCRAMBLE No operation.

TALK attaches a user to a formulary by first conversing with him to obtain a formulary name and then trying to read that formulary into the UCB. More specifically, TALK issues a call to ACCESS with parameters <formulary name>, <location of UCB>+2, and READ. Since TALK always initially attaches the user to the default UCB, the access control procedures ACCESS invokes at this time belong to the system formulary. If this READ attempt is successful, the procedure pointers of the formulary specified by the user are read into the user's UCB, destroying the system formulary pointers previously there.

The READ attempt may in fact not be successful. For example, the user may not be allowed to use the terminal, or the formulary, or the specific data set. The ACCESS program detects these violations (by using the CONTROL procedure of the default UCB) and takes appropriate actions.

4.4.1. Independence of Addressing and Access Control

After the attachment process, the User Control Block (UCB) contains the user identification U, terminal identification T, pointers to the INTNAME, VIRTUAL, CONTROL, SCRAMBLE, and UNSCRAMBLE procedures of a formulary, and (possibly) a data set name. Whether the user can perform read operations, write operations, etc., on a given datum is controlled by the CONTROL program. The addressing of each datum is controlled by the VIRTUAL program. Addressing of datums is now completely independent of the access control for these datums.

4.4.2. Breaking an Attachment

An existing attachment is broken (i. e., the core memory space used by the UCB filled in at that time is cleared and made available for another use) whenever

(1) the user indicates that he is finished using the information storage and retrieval system (either by explicitly declaring so or implicitly by logging out, removing a physical terminal key, reaching the end-of-job indicator in his input card deck, etc.), or

(2) the user is attached to a new formulary.

## 4.5. An Example of Information Storage and Retrieval Using TALK

After TALK attaches the user to the formulary he desires, information storage and retrieval operations can be carried out, as illustrated in Figure 5.

```
!WHAT PROGRAM DO YOU WISH TO RUN?
     medical talk#
!EXECUTION ...
... MEDICAL TALK PROGRAM ...
WHAT FORMULARY DO YOU WISH TO USE?
```

The TALK program asks for the name of the formulary the user wants to use for this session. (Many TALK programs may implicitly attach the user to a prespecified formulary rather than asking the user to explicitly choose one, as this TALK program does.)

```
     health#
```

The user supplies the name, in this case "health".

```
*** SYSTEM FORMULARY --CONTROL-- PROGRAM
```

The system attempts to retrieve the "Health" formulary; we see here execution of the CONTROL procedure of the system formulary which checks whether the user is legitimately entitled to attach to this formulary.

```
TO USE THE HEALTH FORMULARY, YOU MUST BE
PERMITTED ACCESS BY THE COWELL STUDENT
HEALTH CENTER.  WHAT IS YOUR NAME?
```

The CONTROL program asks the user to supply his name. In some systems, it could get the name directly from the operating system, and not have to ask the user explicitly.

```
     lancw hoffman#
LANCW HOFFMAN IS NOT PERMITTED TO USE THE
HEALTH FORMULARY.  A RECORD HAS BEEN MADE
OF THIS REQUEST DENIAL.  PLEASE TYPE YOUR
NAME CORRECTLY THIS TIME.
```

In the case of an illegitimate user, a record is logged of the unsuccessful attempt to attach to the formulary. This record may be examined periodically (or immediately) to determine whether the unsuccessful attempt was simply a misspelling or something more insidious.

```
     lance hoffman#
```

```
WHAT IS YOUR SOCIAL SECURITY NUMBER?
     999-99-9999#
THANK YOU.  YOU ARE PERMITTED TO USE THE
HEALTH FORMULARY.
```

Once the user supplies both the name of a legitimate user and that user's social security number, this specific CONTROL procedure assumes that the legitimate user is in fact really at the console and allows the "Health" formulary to be read into the UCB. At this point, the addresses of the INTNAME, VIRTUAL, CONTROL, SCRAMBLE, and UNSCRAMBLE programs of the "Health" formulary are inserted into the UCB (which already contains the user identification U and the terminal identification T), overwriting the addresses of the previous procedures (of the system formulary ).

```
THE HEALTH FORMULARY HAS BEEN ATTACHED.
*** END OF SYSTEM FORMULARY --CONTROL-- PROGRAM ***
DO YOU WISH TO STORE OR RETRIEVE INFORMATION?
     retrieve#

WHAT INFORMATION DO YOU WISH TO RETRIEVE?
     please give me all female graduate students over 22
     who requested oral contraceptives during the period
     June-September 1968.#

THE REQUEST PARSER HAS REWORDED YOUR REQUEST AS FOLLOWS:

DESCRIPTION 00562:
    RETRIEVE NUMBER OF PATIENTS WITH FOLLOWING CHARACTERISTICS--
         FEMALE
         CLASS=5
         BIRTHDATE < 6 MARCH 1947
         PRESCRIPTIONS INCLUDE
              ORAL CONTRACEPTIVES WITH FOLLOWING CHARACTERISTICS--
                   DATE OF PRESCRIPTION > 31 MAY 1968
                   DATE OF PRESCRIPTION < 1 OCT 1968

IS THIS REWORDING ACCEPTABLE?
     yes#
NUMBER OF PATIENTS IS     247.
```

```
WHAT INFORMATION DO YOU WISH TO RETRIEVE?
     list the identification numbers of all the students who were seen
     for the fall quarter of 1968 with the diagnosis of 977.5 (adverse
     drug reaction)
... CONTROL PROGRAM ...
PLEASE TYPE THE SPECIAL "DRUGS" PASSWORD.
     newhigh#
THANK YOU.  THE PASSWORD IS ACCEPTABLE.  YOUR ANSWER IS:
2546 2377 2598 3310 3367

WHAT INFORMATION DO YOU WISH TO RETRIEVE?
     description 562 and patient in florence moore hall#

THE REQUEST PARSER HAS REWORDED YOUR REQUEST AS FOLLOWS:

DESCRIPTION 00563:
    DESCRIPTION 562 AND
    RESIDENCE = FLORENCE MOORE HALL


IS THIS REWORDING ACCEPTABLE?
yes#
THE RETRIEVAL PROGRAM CANNOT ANSWER THIS QUERY.  THE REASON IS...
    THE NUMBER REQUESTED, IF SUPPLIED BY THE RETRIEVAL PROGRAM, MIGHT
    ALLOW IDENTIFICATION OF PARTICULAR PATIENTS.  IF YOU THINK THIS
    INFORMATION SHOULD BE AVAILABLE TO YOU, PLEASE SEE THE DIRECTOR
    OF THE COWELL STUDENT HEALTH SERVICE.

... A RECORD HAS BEEN MADE OF THIS DENIAL. ...

WHAT INFORMATION DO YOU WISH TO RETRIEVE?
     done#
... END MEDICAL TALK PROGRAM ...

!WHAT PROGRAM DO YOU WISH TO RUN?
```

Figure 5(a). Conversational Retrieval of Data

```
!WHAT PROGRAM DO YOU WISH TO RUN?
     medical talk#
!EXECUTION ...
... MEDICAL TALK PROGRAM ...
WHAT FORMULARY DO YOU WISH TO USE?
     health#
*** SYSTEM FORMULARY --CONTROL-- PROGRAM ***
TO USE THE HEALTH FORMULARY, YOU MUST BE PERMITTED ACCESS BY
THE COWELL STUDENT HEALTH CENTER.  WHAT IS YOUR NAME?
     lance hoffman#
WHAT IS YOUR SOCIAL SECURITY NUMBER?
     999-99-9999#
THANK YOU.  YOU ARE PERMITTED TO USE THE HEALTH FORMULARY.

THE HEALTH FORMULARY HAS BEEN ATTACHED.
*** END OF SYSTEM FORMULARY --CONTROL-- PROGRAM ***
DO YOU WISH TO STORE OR RETRIEVE INFORMATION?
     store#


ANY CORRECTIONS TO EXISTING DATA BASE?
     change record 2549, field 4 from 14 to 15#
     change record 2586, field 2 from F to M#
     #

RECORD 2649.  FIELD 4 WAS 14, NOW 15.
RECORD 2586.  FIELD 2 WAS M.  YOU SAID IT WAS F -- REQUEST DENIED!

     change record 2587, field 2 from F to M#
     #

RECORD 2587.  FIELD 2 WAS F, NOW M.

     #
RECORDS CHANGED: 2549, 2587.

PLEASE ADD NEW DATA.
RECORD 2632:
     999-99-472,m,12/30/47,27,wilbur arroyo,gs,65,327,87#
RECORD 2633:
     999-99-901,f,2/26/49,22,roble,psych,26,338,87,14,47#

                                                .
                                                .
                                                .
RECORD 2805:
     999-99-872,m,8/23/48,26,crothers,4,200,85,53,32,65,84#
***** ERROR -- FIELD 6 (DEPARTMENT) MUST BE ALPHABETIC *****
RECORD 2805:
     999-99-872,m,8/23/48,26,crothers,law,4,200,85,53,32,65,84#
RECORD 2806:
     #
```

```
SUMMARY OF RECORDS UPDATED OR ADDED TO DATA BASE      5 MAR 1969

UPDATED:
2549 999-99-304 M 05/05/45 15 PALO ALTO          MUSIC     33 296  14
2587 999-99-001 F 04/14/43 20 HULME              POLYS     14 256 207

ADDED:
2632 999-99-472 M 12/30/47 27 WILBUR ARROYO      GS        65 327  87
2633 999-99-901 F 02/26/49 22 ROBLE              PSYCH     26 338  87

                                                           14 47
                                        .
                                        .
                                        .
2805 999-99-872 M 08/23/48 26 CROTHERS           LAW       04 200  85

                                                           53 32 65 84

ANY CORRECTIONS?
     #
... END MEDICAL TALK ...
!WHAT PROGRAM DO YOU WISH TO RUN?
```

Figure 5(b). Conversational Storage of Data

Figure 5. Storage and retrieval of data in a specific system.

## 5. Summary

In this paper, we have described the formulary method of access control. This method allows the functions of data addressing and access control to be separated and performed at data access time by independent programs of arbitrary complexity. It thus represents a step forward from previous methods which used prespecified, static information to determine access privileges. Using the access control procedures of a formulary, the decision on access privileges can now take account of such factors as time of day, terminal identification, and the value of the data requested (or of other data). These procedures can interact with the user to further validate his identification and his rights to access the information in question.

## 6. Acknowledgments

The author is most grateful to Professor William F. Miller for his encouragement and advice. Many other members of the Stanford Computer Science Department and the Stanford Linear Accelerator Center have also contributed their ideas and help, in particular John V. Levy and Victor Lesser. The formulary idea was initially suggested by the use of syntax definitions ("field formularies") for input/output data descriptions, as described in (Castleman [ ] . The library staff at the Stanford Linear Accelerator Center has been most helpful in tracking down articles on the topic. Editing of this paper was facilitated by using a text editor for the IBM 360/91 written by J. E. George.

Appendix A. Algorithms for System Programs

```
INTEGER PROCEDURE access(field, value, length, opn);
BEGIN COMMENT Access takes as input the natural language field name field
and does the following:
If opn =  "READ" or "READANDLOCK" , value is set to the value of field.
If opn =  "WRITE" or "WRITEANDLOCK", the value of field field becomes value.
If opn =  "READANDLOCK" or "WRITEANDLOCK" the datum is locked after the
     READ or WRITE operation is performed.
VALUE has length length.
Access returns the following integers as functional values:

     1   normal exit, no error
     2   natural language field name/internal name correspondence cannot be
          made using INTNAME from UCB
     3   Opn permitted but gave error when attempted
     11  Opn not permitted by the CONTROL program associated with datum
          specified by field

Note that by the time the user has left the ACCESS routine, the data may
have been updated;

IF intname(field, intnamep) = 2 THEN BEGIN j:=2; GO TO FIN END;
COMMENT Return 2 if intname cannot make the correspondence;
IF opn="UNLOCKREAD" or opn="UNLOCKWRITE" THEN
     BEGIN apply(opn,intnamep); COMMENT clear a read lock or a write lock;
     j:=1; GO TO FIN; COMMENT and then exit;
     END;
vtemp:=control(intnamep,
     if opn="READ" then "GET" else
     if opn="WRITE" then "PUT" else
     IF opn="READANDLOCK" then "GETANDLOCK" else
     IF opn="WRITEANDLOCK" then "PUTANDLOCK" else opn);
IF car(vtemp)=2 THEN BEGIN COMMENT control does not allow operation;
                           j:=11; GO TO FIN;
                           END;
virtual(intnamep,datum, cdr(vtemp));
COMMENT Datum now holds the virtual address of the datum specified;
i:=try2(opn,car(datum),reslt,length);
IF i > 2 THEN BEGIN COMMENT exit since opn operation failed;
                    j:=i; GO TO FIN;
                    END;
COMMENT Perform physical read (write) of size length to (from) block starting
     at reslt;

COMMENT This next may happen after the (un)scrambled data has gone over
the line from (to) the central memory to (from) the console's computing
device;
value:=apply(IF opn="READ" or opn="READANDLOCK" then unscramble ELSE scramble,
     reslt, length);
IF car(value)=1 THEN BEGIN value:=cdr(value); j := 1;
                           COMMENT Successful completion of
```

Access procedure;

END

```
ELSE
COMMENT error in performing opn so return 3; j:= 3;
FIN:
RETURN j; COMMENT completion code;
END access;
```

```
INTEGER PROCEDURE try2(F,p1, p2, ..., pn);
     INTEGER PROCEDURE F; CELL p1, p2, ..., pn;
                    BEGIN COMMENT try2 is a service routine used mainly to call and wait
                    for completion of other routines which may need to access data that
                    is temporarily locked out.

                    Inputs: F, a function name
                            p1, p2, ..., pn
                    Output: 1 on normal exit
                            The value returned by F on abnormal exit;

                    INTEGER errcode;
ATTEMPT:
                    errcode := F(p1, p2, ..., pn);
                    IF errcode = 2 THEN GO TO ATTEMPT;
                    COMMENT Locked out temporarily if errcode = 2;
                    RETURN errcode
                    END try2;
```

# Appendix B.
# Primitive Operations

Primitive operations are those which cannot be expressed in machine-independent form, but rather depend on the specific system and machine used. They are defined in terms of their inputs and outputs.

GET(addr, value, length)

GET returns in length storage elements starting at value the value contained in the virtual address addr. This value may be scrambled. GET returns as its own value:

1 if normal exit
2 if addr is currently blocked
3 if GET cannot access length storage elements starting at value

PUT(addr, value, length)

PUT stores the contents of value into length storage elements starting at virtual address addr. The information stored may be scrambled. PUT returns as its own value:

1 if normal exit
2 if addr is currently blocked
3 if GET cannot write length storage elements starting at addr

GETANDLOCK(iname,value)

GETANDLOCK operates in the same way as GET except that it takes as the specification of the datum its internal name rather than a virtual address. By doing this, GETANDLOCK is able to (and does) simultaneously lock out internal name iname to all further requests by storing it and the user identification U in the LOCKSTACK. It is the responsibility of the user to, when he is ready, free the locked datum (specified by iname )by calling UNLOCK(iname). If this has not been done by the time the user logs off the system, it is automatically done by the system.

If User 1 locks out datum D which he knows by the natural language description N1, and User 2 then attempts to access datum D (which User 2 knows by the natural language description N2), the request of User 2 is denied (i. e., GET returns 2 when invoked for User 2).

GETANDLOCK returns as its own value:
1 if normal exit
2 if intname is currently blocked
3 if GETANDLOCK cannot access length storage elements starting at value

PUTANDLOCK(iname,value)

PUTANDLOCK is analagous to GETANDLOCK.

UNLOCKREAD(iname)

UNLOCKREAD unlocks the read-lock which had been put on the datum specified by the internal name iname by a previous call to GETANDLOCK or PUTANDLOCK. This is done by removing the appropriate doublet from the LOCKSTACK. UNLOCKREAD returns as its own value:

1 normal return
2 iname did not specify a datum locked by this user

UNLOCKWRITE(iname)

UNLOCKWRITE is analagous to UNLOCKREAD.

APPLY(x,y)

APPLy applies the function named in x when given the list y of arguments. It returns the value of the function.

CAR(x)
CAR returns the first element of the list x.

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