An Introduction to Information Science
I

Introduction

This section provides an overview for the course. It includes a rather simple but fairly thorough example of information science as question-answering. The purpose of the example is to illustrate the generation of an information need by an action that is blocked due to lack of knowledge, the eventual resolution of the need by an appropriate "data response," and the use of this answer in completing the original goal-directed action. Hence, information is viewed as data that enables effective action, i.e., knowledge relevant to a given situation. Data is taken in the broad sense of (1) a model of the situation, and (2) values for the variables appropriate to the model.

As indicated above, a need for information arises as a result of an action that is blocked due to lack of knowledge—an "information problem."

The information need is expressed in the form of a question. The genesis of the need and its representation in a question leads to information-seeking behavior, the result being an answer to the question posed. This answer takes the form of a list of actions deemed sufficient to obtain the goal initially sought and blocked. If more than one answer is identified as sufficient for obtaining the goal, the agent is required to make a choice; that is, to enter into the act of decision-making. Finally, having made a decision, the chosen action is implemented.

Hence, the cycle from information need to information use is:

- Goal-directed activity blocked by lack of knowledge (information problem).
- Formulation of lack of knowledge in the form of a question (information need).
- Response to the need by seeking data (information-seeking behavior).
- Generation of zero or more answers. If list of answers:
  - is empty, than a solution is impossible at this time.
  - contains only one item, it is possible to move to the implementation stage.
  - contains more than one item, it is possible to choose among actions (decision-making) then move to implementation.

The occurrence of the first result, a null answer, may be due to the lack of a proper model for the situation at hand or to an inability to estimate
the values of the relevant variables in that model. There is no choice here but to develop (or find) either such a model or a suitable estimation procedure. The action will remain blocked until either can be done.

The cycle of information generation/utilization does not require the external storage and retrieval of information. However, assuming that the situation in which the blockage occurred has a high probability of recurring or that the situation is important enough to require preparation for its reoccurrence even if that reoccurrence is of low probability, we will record the data for future use. This leads to the question of physical coding of data, its logical organization in representing entities and events, and its physical organization in file structures that will enable efficient storage or fast retrieval. The storage decision is an expected utility decision, balancing the expected value of the situation, that is, the probability of reoccurrence times the value of correct action against the costs of (1) storage and retrieval, or (2) regeneration of the data on demand.

Finally, since the information system is often automated, we enter into the realm of human/machine communication and data displays. One use of displays is to present output data. Another is to present options that the user has (menus) or to guide data entry (data forms). The study of displays is "1-way" communication. The topic of human/machine communication extends the discussion to include 2-way communication, i.e., conversation. The user puts commands, questions, and data to the machine, and the machine returns "results" by searching data bases and by performing operations on the input or stored data.

Notably absent from the scenario as so far presented (until the last sentence of the previous paragraph) is data manipulation, traditionally considered one of the mainstays of information science. In the model presented here, data manipulation is an auxiliary activity, but necessary in order to bring the data into a form in which it can be used. The form is dictated by the model the agent is using in coping with the relevant situation. For textual data, the manipulation may be as simple as a sort, presenting the more salient items of the model "before" the less salient features. For numerical data the manipulations are arithmetic or logical transformations dictated by equations used in the mathematical model. In this light the activities of data processing are necessitated by the fact that data are often collected in a form that is not directly usable, but are "fed into" a transformation processor that "massages" them into the desired form. One of the models so used is a model of the generation of knowledge, which involves statistical manipulation of data in order to make statements about the world. Other models are more application oriented, e.g., the use of market research in order to estimate demand for a product or services.

While the example presented in the first chapter is relatively "light" in nature, it is purposely so. The example is meant to serve as an advance organizer for the topics presented throughout the text. The text itself is skill oriented, establishing a minimal set of skills that enable one to interact with the scientists and professionals involved in studying and using information, both as an end in itself and as a means to effective action.
1

Information Science as Question-Answering

Objectives

The purpose of this chapter is to set the stage for the rest of the text. Various topics that reoccur in the study of information and information systems are here presented through an example instead of formally. The example, obtaining lunch in a strange town, is a simple one. However, it involves most of the concepts that are treated more formally in later chapters. It is meant to be a painless introduction, and has been useful as the introductory lecture in the first course in information science taught at the University of Pittsburgh, where it has been shown to be an introduction to which the students can intuitively relate.

In contrast to the remaining chapters of the text, the emphasis in the first chapter is on an overall understanding of concepts rather than of particular skills, terms, and procedures. However, the reader should obtain some sense of the following:

1. The relationship of questions and answers to problem-solving and decision-making
2. The components of an information system: acquisition, transmission, processing, storage and retrieval, and display
3. The process by which one makes decisions, e.g., the calculation of an expected value
4. Sources of error and failure in an information system, e.g., coding errors, lack of accuracy in the data, lack of timeliness in providing the data, or the provision of irrelevant data

Introduction

The approach to information science taken in this text is one of question-answering. The reason for this approach is that it is readily comprehensible. We have all experienced information booths, say in the lobby of a large building or hospital, and we recognize them as places to go up to have our questions answered. We also have used the information services of telephone companies, which respond to our needs by answering very specific ques-
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tions, such as "What is the phone number of my friend, Anthony Michaels?" with such data as "422-7543." Because of this common bond of experience, it is relatively easy to expand the process of question-answering into the concepts, techniques, and procedures that information professionals encounter during their everyday activities. A more general approach would be to take information science as the study of the generation, preservation, and communication of information. We will use both models as convenient.

An Example

An overview of the activities involved in generating and using information can be given through the use of a simple example. We have just arrived in a strange town, by bus, at noon, and we are hungry. One of our problems is to find a place to eat.

Collecting the Data

One of the first steps we must take is to collect data on the restaurants in the area. We may do this by consulting a document, such as the phone book, wherein we would look up "restaurants" in the yellow pages. In terms of the generic data collection methods, we would call this the use of archives, which are records (documents, data) already collected and organized by someone else. In this case, the someone else is the phone company. An alternate method of data collection would be to ask someone who seems to be a native, say, the person selling newspapers. This would be the method of data collection called report-by-others.

Whatever the method by which we collect the data, the result of our efforts will be a list of names of restaurants, in this case:

Joe's Diner
Swank-U-Pay
Mary's Place

Choosing a Technology

This list now exists in the phone book or in the mind of the newspaper vendor, as well as in the mind of the person seeking the information. If we do not trust our memory, we might wish to store this information on a sheet of paper that we can carry in our pocket—an external storage medium. In order to do this, we need some minimal technology, e.g., a writing device such as a pencil, and a storage medium such as a piece of paper or a notebook. Using this technology, we would copy certain portions of the information from the phone book (or newspaper vendor's verbal comments) to the sheet of paper. If we restrict our attention to the case of the phone book, one or two more points may be made in regard to storing the data.

Choosing the Relevant Data

The data in the phone book may include information for which we have no need. For example, if the listing is a paid advertisement, it might look like
Joe's Diner
Hamburgers
Pizza
We do the best for you
Open 10AM till Midnite
7 Days a Week
247 North Avenue
Call 422-7513

FIGURE 1.1

Figure 1.1. We would obviously not record every piece of data. In fact, it is likely that only the name of the diner, the address, and the phone number would be of use to us. We would record only those items and omit the rest. We know that the menu (hamburgers, pizza) will be available later, at Joe's, and the judgment "We do the best for you" is a "self-report" (another method of data collection) that is no doubt biased to some degree. We might or might not record the hours that the restaurant is open (10 A.M. to midnight) and the days (7 days a week). The decision to record or not to record this information would depend on our purposes. For example, if we wish to use the information this one time only, we would most likely not record the information. This would be the case if we were on a stopover, planning to leave town again shortly, and not to return. In this case, we would simply note the hours open, compare them to the current hour (noon), observe that the restaurant is now open, then discard the information.

On the other hand, if we were coming to town to take a new job, and thus planning to stay, we might well expect to return to the restaurant more than once. In this case, we would record the hours and days that the restaurant is open.

The point to be made here is that the information that we "store" ("record," "save") depends on the probability of our needing to retrieve the information in the future. If we intend to use the information again, we save it. In this example, we will need the name of the restaurant (its label) in order to identify it when we arrive at its location. We also need its location (address) in order to find the restaurant, and we might record the phone number in case we get lost en route. If we were confident of not getting lost, we might not record the phone number. In any case, the information we gather is only that which is relevant to our purposes.

Coding the Data

In recording the information, we will no doubt take shortcuts, recording "Joe's" as a shortened version of "Joe's Diner," and "Ave." as a shortened version of "Avenue." This process of recording the information in short form is known as coding. Coding is one aspect of the more general problem of data representation. In this sense the code is a representation of meaning, a physical means of recording statements about ourselves and our environment.
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Besides representing meaning, the choice of a proper code is dependent on the medium used to store and transmit data, as well as the devices used to process it. If we expect to process the data by computer, it will be stored in the form of a computer code, such as ASCII, EBCDIC, or binary. The transformation from one code to another is also dictated by the circumstances of processing, storing, and transmitting the information. These activities often involve the translation of the data from one medium to another. In the case of collecting the data from the phone book, the data is already stored in the medium of the printed page; we transform the code to a mental image by reading the data (device: eyes; medium of storage: the neural system and the brain), then transform this mental image to another written code, our notations on a sheet of paper (device: pencil; medium: paper). In the case of asking the newspaper vendor, his or her mental code is transformed into a verbal code (speech or natural language) at our request, transformed again from the person's speech to our mental code, and transformed again to the written notation on the notepad.

Manipulating the Data

In addition to coding the data, we may manipulate it in some way. The manipulation might be noncomputational, e.g., putting the list of restaurants in alphabetical order, or it may be computational, e.g., comparing the distances to each restaurant. For example, let us suppose that the following are the restaurants we have found in the vicinity:

- Mary's Place 1312 East End
- Joe's Diner 247 North Avenue
- Swank-U-Pay 49 Upper Avenue

One method of manipulating this list would be to put it in alphabetical order by restaurant name:

- Joe's Diner 247 North Avenue
- Mary's Place 1312 East End
- Swank-U-Pay 49 Upper Avenue

An alphabetical listing would be useful if we expected to create a fairly large file over an extended period of time, since the ordering of the list by name would facilitate retrieval. Other types of organization might be by type of restaurant or by price range. The alphabetical listing is typical of files organized by "key" (or identification field). The organization by type of restaurant is characteristic of files organized on secondary fields (called inverted files). The type of file organization chosen depends on the size of the file and the access patterns to the data: how often we access the file (frequency of access), how many items we access (activity), how fast we need a response (response time), and the type of access (to insert data, delete data, update the data elements, or simply search for and display a particular data record). A short list, such as our list of restaurants, can be stored in almost any fashion, since it can be scanned quickly. Longer lists will need an organization suited to the purposes for which the data is retained. The purposes are determined by the "user" of the information.

In this particular example the distance to the restaurant might be of interest to us. If we are on a stopover with limited time, the distance can
outweigh considerations of taste or cost of food, decor, and the like. If
distance were a factor, we would embark on another effort at data collec-
tion, consulting a map (another form of existing records or archived infor-
mation), the newspaper vendor, etc. In the case of the map, we would be
involved in the transformation of information stored as a series of lines and
spaces between the lines into a numerical representation, such as "2 blocks
away." The list would then be ordered by distance:

1 block    Swank-U-Pay
2 blocks    Joe's Diner
3 blocks    Mary's Place

at least mentally, if not on the physical medium.

Using the Data

If distance were the only factor of interest to us, we could now choose the
nearest, Swank-U-Pay, and begin walking in that direction. Of course,
factors other than distance could be involved: e.g., the cost of the food,
its taste, the atmosphere of the restaurant, and the friendliness of the
people who work there. If this is the case, we become involved in the pro-
cess of decision-making, evaluating each restaurant on each criterion.

Problem-Solving and Decision-Making

The original situation, finding a place to eat, is a type of problem situation.
One definition of a problem is a discrepancy between the current state of
affairs (being hungry and not knowing where to eat) and some desired
state (the goal). The essence of the solution to the problem is to find a
sequence of actions through which we can pass from the current state to
the goal state. In our case this involves the identification of the restaurants
and the directions to each restaurant.

If the list of alternative actions contains more than a single alternative,
the "user" of the information passes from the stage of problem-solving to
the stage of decision-making. The task is to select one alternative from the
many. This may be done haphazardly, by simply choosing "at random" or
in a more systematic manner. The systematic approach to decision-making
would involve the identification of the relevant criterion with respect to
our goals, the evaluation of each alternative on each criterion, the formula-
tion of some measure by which to summarize the individual evaluations, and
the comparison of the alternatives according to their rating on the sum-
mary measure.

A Decision Matrix

In order to evaluate the alternatives, we might create a decision matrix
(Figure 1.2). The criterion or parameters of choice are those set by the
decisionmaker. These will reflect the characteristics of the situation (what
criteria are relevant to achieving the goal) as well as personal preferences,
e.g., if taste is a more important concern than cost.
Establishing the Values

The creation of the decision matrix introduces the notion of "subinformation goals": the evaluation of each alternative on each criterion. We must establish some measure that will allow us to fill in values for each blank line.

The criteria have been transformed into questions that can be answered "yes" or "no," and these questions have been phrased in such a way that "yes" is always good and "no" is always bad (e.g., good taste?, low cost?).

As a first attempt at making a decision, we simply fill in the matrix with these "yes" or "no" answers (Figure 1.3a). The yes/no ratings categorize the restaurants on each alternative. The restaurants Joe's Diner, Mary's Place, and Plain Home Cooking belong to the category of restaurants serving good food (or, stating it another way, they have the property of serving good food). The restaurants Eat-A-Burger and Swank-U-Pay lack this property. The classification is both exhaustive and mutually exclusive, with all restaurants being classified and none falling into two different sets on the same category, Figure 1.3b.
Dimension: Taste

<table>
<thead>
<tr>
<th>Good Restaurants</th>
<th>Bad Restaurants</th>
</tr>
</thead>
<tbody>
<tr>
<td>1, 2, 5</td>
<td>3, 4</td>
</tr>
</tbody>
</table>

**FIGURE 1.3b**

The categorization is independent for each dimension, so that we need a summary measure to evaluate the restaurants across all three dimensions. In the case of the yes and no responses, a simple count of the yes classifications will do, resulting in the choice of Mary's Place as the preferred means to our goal. In counting the yes responses, the assumption is that each criterion is equally important. If this is not the case, the dimensions would be "weighted" according to their relative importance.

Quantitative Scales

A more refined method of measuring would grade each restaurant on a three-part scale (good, fair, and poor), or even a five-part scale (very good, good, fair, poor, and very poor).

A matrix for a three-part scale of good, fair, and poor might look like Figure 1.4. The matrix is consistent with the previous scale if the ratings of fair and good are replaced by "yes," the rating of poor replaced by "no." Yet the refinement of the scale brings with it problems of summarization. Are two fairs equal to one good? Is a good and a poor equal to one fair?

The decision to count two goods and a poor as "better" than one good and a fair results in number 5, Plain Home Cooking being the choice over number 2, Mary's Place, which was the "winner" on the yes and no scale.

The yes and no scale obliterated any difference between fair and good. This "smoothing" or "smearing" of the difference, coupled with the decision

<table>
<thead>
<tr>
<th>Restaurant</th>
<th>Good taste?</th>
<th>Low cost?</th>
<th>Nearby?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Joe's Diner</td>
<td>Fair</td>
<td>Good</td>
<td>Poor</td>
</tr>
<tr>
<td>2. Mary's Place</td>
<td>Fair</td>
<td>Good</td>
<td>Fair</td>
</tr>
<tr>
<td>3. Eat-A-Burger</td>
<td>Poor</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>4. Swank-U-Pay</td>
<td>Poor</td>
<td>Poor</td>
<td>Poor</td>
</tr>
<tr>
<td>5. Plain Home Cooking*</td>
<td>Good</td>
<td>Poor</td>
<td>Good</td>
</tr>
</tbody>
</table>

**FIGURE 1.4** *Indicates our choice*
rule on weighting goods, fairs, and poors is responsible for the change in
the decision. Both the rating scales and the summarization procedures are
different in the two examples.

The matrix in Figure 1.5 was constructed with "fair" representing a
middle area that was originally evaluated as "yes" in some instances, as
"no" in others. Again, the example indicates that the choice of the scale
and measurement technique can substantially influence the decision.

As the scale becomes more refined it is useful to move from a categori-
cal classification scheme to a numerical scale, say 1 to 10, with 10 being
the best. The summary measure now becomes a matter of addition of ratings,
if we assume the criteria are equally weighted (Figure 1.6). The matrix is
consistent with the previous matrices if ratings 8 through 10 are taken as
having produced unequivocal "yes" responses on the previous ratings,
ratings of 1 through 3 having produced judgments of "no;" and ratings of
4 through 7 having produced the ambiguous "fair," which may have re-
ceived some "yes" judgments and some "no" judgments in the first matrix
presented.

<table>
<thead>
<tr>
<th>Restaurant</th>
<th>Good taste?</th>
<th>Low cost?</th>
<th>Nearby?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Joe's Diner</td>
<td>Poor</td>
<td>Good</td>
<td>Poor</td>
</tr>
<tr>
<td>Mary's Place</td>
<td>Fair</td>
<td>Good</td>
<td>Fair</td>
</tr>
<tr>
<td>Eat-A-Burger</td>
<td>Poor</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>Swank-U-Pay</td>
<td>Fair</td>
<td>Poor</td>
<td>Fair</td>
</tr>
<tr>
<td>Plain Home Cooking*</td>
<td>Good</td>
<td>Fair</td>
<td>Good</td>
</tr>
</tbody>
</table>

*Indicates our choice
Weighting the Criteria

The above examples treated all criteria as equally important, but this is not always the case. A fairly rich person might consider taste to be very important, cost inconsequential. Someone less financially blessed, perhaps a student, might have a different set of priorities. The priorities may be a result of objective factors in the situation, such as the lack of money, or of subjective factors, such as a preference for nice decor over a preference for a particular type of food. The objective factors would be the constraints within which the decision has to be made (and the problem solved). The subjective factors would be constraints inherent in the particular decision-maker (agent of the action), and would differ across decisionmakers.

One method of assigning weights is to assign values from 0 to 1 so that all portions add to 1 (exactly as probabilities are assigned). A taste-conscious decisionmaker might assign the values:

<table>
<thead>
<tr>
<th>Restaurants</th>
<th>Good taste?</th>
<th>Low cost?</th>
<th>Nearby?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Joe's Diner</td>
<td>.5</td>
<td>.3</td>
<td>.2</td>
</tr>
<tr>
<td>Mary's Place</td>
<td>6</td>
<td>9</td>
<td>2</td>
</tr>
<tr>
<td>Eat-A-Burger</td>
<td>3</td>
<td>10</td>
<td>9</td>
</tr>
<tr>
<td>Swank-U-Pay</td>
<td>4</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Plain Home Cooking</td>
<td>10</td>
<td>4</td>
<td>9</td>
</tr>
</tbody>
</table>

(a)

<table>
<thead>
<tr>
<th>Restaurants</th>
<th>Good taste?</th>
<th>Low cost?</th>
<th>Nearby?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Joe's Diner</td>
<td>3</td>
<td>2.7</td>
<td>.4</td>
</tr>
<tr>
<td>Mary's Place</td>
<td>3</td>
<td>2.4</td>
<td>1.4</td>
</tr>
<tr>
<td>Eat-A-Burger</td>
<td>1.5</td>
<td>3.0</td>
<td>1.8</td>
</tr>
<tr>
<td>Swank-U-Pay</td>
<td>2</td>
<td>.3</td>
<td>0.8</td>
</tr>
<tr>
<td>Plain Home Cooking*</td>
<td>5</td>
<td>1.2</td>
<td>1.8</td>
</tr>
</tbody>
</table>

(b)

FIGURE 1.7 *Indicates our choice
### Criteria

<table>
<thead>
<tr>
<th>Restaurants</th>
<th>Good taste?</th>
<th>Low cost?</th>
<th>Nearby?</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Joe's Diner</td>
<td>.6</td>
<td>7.2</td>
<td>.2</td>
<td>8.0</td>
</tr>
<tr>
<td>Mary's Place</td>
<td>.6</td>
<td>6.4</td>
<td>.7</td>
<td>7.7</td>
</tr>
<tr>
<td>Eat-A-Burger*</td>
<td>.3</td>
<td>8.0</td>
<td>.9</td>
<td>9.2</td>
</tr>
<tr>
<td>Swank-U-Pay</td>
<td>.4</td>
<td>.8</td>
<td>.4</td>
<td>1.6</td>
</tr>
<tr>
<td>Plain Home Cooking</td>
<td>1.0</td>
<td>3.2</td>
<td>.9</td>
<td>5.1</td>
</tr>
</tbody>
</table>

**FIGURE 1.8** *Indicates our choice

<table>
<thead>
<tr>
<th>Taste</th>
<th>Cost</th>
<th>Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>.5</td>
<td>.3</td>
<td>.2</td>
</tr>
</tbody>
</table>

A person who considers distance to be an important criterion might choose the following weights:

<table>
<thead>
<tr>
<th>Taste</th>
<th>Cost</th>
<th>Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>.1</td>
<td>.1</td>
<td>.8</td>
</tr>
</tbody>
</table>

These weights would be used to adjust the points awarded to each criterion. One method of computation is to multiply each rating by the weight, then sum the results to obtain an "average" rating (or expected value). For the matrix in Figure 1.7a, the weighted ratings would be those shown in Figure 1.7b. This decisionmaker, adhering to the use of the expected value calculation, would choose restaurant 5. The decisionmaker weighting cost most heavily arrives at a different choice given the same restaurants and the same ratings (Figure 1.8).

### Other Criteria

Of course, the three criteria of taste, cost, and proximity are not the only criteria that might apply. "Prestige" might be an important factor to some restaurant goers, and, assuming that Swank-U-Pay has a large prestige factor, it could rise rapidly in the rankings.

The actual decision that is made is not as important to the information specialist as the ability to fill in the necessary information to make that decision:

1. The list of restaurants
2. The list of criteria
3. The relative weight to be assigned to each criterion by the decisionmaker
4. The ratings of each restaurant on each of the criteria
5. The computation of the total score for each restaurant
6. The comparison of the summary tools, yielding a ranked list of choices or a single "overall best" choice
Cost conscious

1. Eat-A-Burger 9.2
2. Joe's Diner 8.0
3. Mary's Place 7.7
4. Plain Home Cooking 5.1
5. Swank-U-Pay 1.6

Taste conscious

1. Plain Home Cooking 8.0
2. Mary's Place 6.8
4. Joe's Diner 6.1
5. Swank-U-Pay 3.1

FIGURE 1.9

Data Display

Step 6 addresses the output of the data results. One suitable display for the data on restaurants would be a ranked list. For the decisionmakers in question, the two lists would exhibit a different order, reflecting the per-

<table>
<thead>
<tr>
<th>Restaurants</th>
<th>Good taste?</th>
<th>Low cost?</th>
<th>Nearby?</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Joe's Diner</td>
<td>3</td>
<td>2.7</td>
<td>4</td>
<td>6.1</td>
</tr>
<tr>
<td>Mary's Place</td>
<td>3</td>
<td>2.4</td>
<td>1.4</td>
<td>6.8</td>
</tr>
<tr>
<td>Eat-A-Burger</td>
<td>1.5</td>
<td>3.0</td>
<td>1.8</td>
<td>6.3</td>
</tr>
<tr>
<td>Swank-U-Pay</td>
<td>2</td>
<td>.3</td>
<td>0.8</td>
<td>3.1</td>
</tr>
<tr>
<td>Plain Home Cooking</td>
<td>5</td>
<td>1.2</td>
<td>1.8</td>
<td>8.0</td>
</tr>
</tbody>
</table>

(a) Display 1

<table>
<thead>
<tr>
<th>Restaurants</th>
<th>Total score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Choose</td>
<td></td>
</tr>
<tr>
<td>Plain Home Cooking</td>
<td>8.0</td>
</tr>
<tr>
<td>Mary's Place</td>
<td>6.8</td>
</tr>
<tr>
<td>Eat-A-Burger</td>
<td>6.3</td>
</tr>
<tr>
<td>Joe's Diner</td>
<td>6.1</td>
</tr>
<tr>
<td>Swank-U-Pay</td>
<td>3.1</td>
</tr>
</tbody>
</table>

(b) Display 2

FIGURE 1.10
sonal preferences of the decisionmakers, although the principle behind each listing is the same (Figure 1.9).

The summary data are often more readily comprehensible than a complete listing. The complete listing is shown in Figure 1.10a. The data of interest are hidden in the full display, but highlighted in the summary display, Figure 1.10b. The price for this highlighting is the loss of detail. Given only the summary display one cannot tell whether Plain Home Cooking was judged superior because of the taste of its food, its economic pricing structure, or its proximity. In fact, one cannot even tell that these were the three criteria involved. The trade-off between economy of information transmitted or stored versus its completeness is a recurring issue. Similar trade-offs will be encountered between using up storage space to save processing time and vice versa, as well as between the time spent organizing input data at the time of storage versus the time spent searching for it at the time of retrieval.

Implementation of the Chosen Alternative

Once a decision has been made, the chosen alternative must be implemented. In our case, we must proceed from the bus station to the restaurant of choice, order the food, eat it, pay for it, and return to the bus station. The successful implementation of the chosen course of action will not always depend solely on our own efforts. It may also involve certain "states of nature" or the actions of other agents. If we are walking to the restaurant, our progress involves monitoring traffic patterns and traffic signals. If a car is in our path or if the traffic light is red, we must temporarily suspend our progress. Our "course of action" involves a subset of actions, some of which are conditional in nature:

If traffic is heavy, wait before crossing.
If road is clear, cross.

To tell if the conditional portion of the statement is fulfilled, we must monitor the environment for ongoing indications of its "status" (the state of the world) and adjust our actions accordingly.

To judge the effectiveness of our actions we also become involved in "feedback" loops, i.e., monitoring the effects of our actions. In walking to the restaurant, we may watch the addresses of the buildings we pass. If the bus station is at 355 West Main and the restaurant is at 632 West Main, the addresses should continually increase until we arrive at the intended location. Indications of error in our execution of the action would be decreasing addresses or addresses larger than 632 West Main. In either case the solution of the problem is to turn around, i.e., to adjust our action by walking in the opposite direction. The adjustment of our input action (walking in a particular direction) by the analysis of the effects of our action (the output, here the sequence of addresses) is what is meant by feedback. We feed back the results of our actions to the input control mechanism.

Evaluating the Information

One means of evaluating the information we generate and use is to examine it in relationship to the success of the chosen action in achieving the goal.
Lack of achievement can be due to physical factors (a bridge is out on the road from the bus station to the restaurant) or deficiency in the knowledge base (the restaurant is no longer at the location named in the phone book). Achievement of the goal indicates that neither difficulty occurred. The information used is a conjunction of the correct list, correct evaluation of the alternatives, and correct information about the respective states of the environment and ourselves in the implementation stage. Some portions of the data might have been incorrect, e.g., the rating of a restaurant not chosen might have been too high; since the data was not used it would not be uncovered. Since the error is on the high side, and we still did not choose that alternative, the error had no bearing on our final choice. An error on the low side, rating taste as a 6 instead of a 10, could have substantially altered the decision and may have caused our decision to be less than optimal, although the subjective judgment of a successful outcome indicates that the action was at least satisfactory. In many situations the number and complexity of factors influencing the outcome, along with constraints on time and funds, force the decisionmaker to "satisfice" rather than optimize.

The assessment of the outcome is an indirect measure of the quality of the information. Direct measures are its accuracy, relevance, and timeliness. The accuracy of the data is its "truth value." Do the data statements represent the real state of affairs? The relevance of the data concerns its applicability to this particular situation. Examples failing the test of accuracy are innumerable: inclusion in the list of a restaurant that has gone out of business, wrong recording of the address, wrong ratings, etc. The error "restaurant out of business" indicates the time dependency of data statements, requiring continual update to maintain the quality of the data. Such errors as an incorrect address are often due to the transposition of digits (recording 49 as 94), simple transcription errors (recording N. and S.), or incorrect spelling. Techniques of error detection and correction, such as limit checks, digit checks, and "spell" dictionaries, are used to uncover such as errors. Errors of omission can occur, such as the absence of street signs, as well as errors of data communication, such as poorly designed displays.

Examples of irrelevant data would be a list of movie theaters rather than restaurants, ratings on irrelevant criteria, and signals from the environment that are not applicable, say the signaling of a train on tracks that are not in our path. I was going to say the sounding of a foghorn to signal the lunch hour at a local factory, but this would be relevant, if unanticipated, information to a restaurant seeker.

Nonrelevant data is problematic because of its "noise" effect. It distracts the consumer of the information from the relevant data, as a skillful propagandist well knows. Examples are often found in responses to essay tests.

The timeliness of the data addresses the question of its being generated or retrieved in the time frame necessary to take action. Taken in this sense it is a factor of efficacy, taking efficacy as the ability to achieve the given goal. The efficacy is in terms of influencing the action rather than producing it. The influence consists of an indication of the correct action (accuracy) in the context of the situation (given goal and state of the environment) in the time frame necessary to act. The contextual constraints may involve other resources, such as the funds and technology available, and social and legal constraints, but the concern voiced most
often is with regard to time, since failure on this point will make the other concerns inconsequential.

It may seem that relevance is a measure of the efficiency of the information system rather than a measure of the efficacy of the information itself, and the term is so used in the evaluation of bibliographic retrieval systems. However, the relevance of the data is also a necessary condition of continued, controlled efficacious action (haphazard success may occur sporadically but in a manner outside out repeated control).

Evaluating the Information System

Various definitions of systems are offered in almost every discipline. They usually have the flavor of a set of entities interacting (e.g., physical systems) or a set of entities and the relationships among them (abstract or physical systems). Information systems are taken to be a set of people, procedures, and technology used to provide information. In evaluating such a system we would first look at the accuracy, relevance, and timeliness of the data, and the efficacy of the information produced. Given that two or more systems are efficacious, they would then be evaluated along the lines of efficiency, the cost in terms of resources necessary to produce the information. Costs are often reckoned in terms of money, time, and human effort. Time appears in a different role here: in terms of efficacy, the time constraint is an upper limit on the length of search. Having satisfied this upper limit, differences may still exist between two systems. The human effort expended may be physical (fatigue at a terminal) or mental (effort expended in sorting through nonrelevant data, which is why this is used as a measure of efficiency as well as efficacy). The design of an efficient and effective information system requires the analysis of user needs (what questions will be asked, under what constraints) and the matching of technology (computer processing versus manual) and procedures (organization of data, direction of data flow, methods of preserving the integrity of the data) to fit those needs.

A major question in the design of such a system is the anticipatory nature of the information need. Predictable questions can be handled quite efficiently (or not at all if we preclude the question with a periodic report), as exemplified in the telephone information system. The predictability may be due to the repetitiveness of certain situations (e.g., it is always unbearable in Chicago in the winter) or to dicta (e.g., we will accept questions about phone numbers in our city, but not about recipes for baked goods). "Generalized" information systems, such as the general purpose library, are inherently less efficient. They inevitably collect data that have potential use, but the potential is not always actualized. Yet the collection of only data that are relevant to expected situations can hinder the efficacy of the information system. When unanticipated needs arise, the data at hand are not usually sufficient. The trade-off is between efficacy across all situations, even the unanticipated, and efficiency for a particular anticipated situation.

The Components of an Information System

While various models of an information system are given, they usually include the following components:
1. Data acquisition
2. Data processing
3. Data storage and retrieval
4. Data transmission
5. Data communications

One or more components may receive emphasis in a particular system. Data entry systems and real time monitoring systems will emphasize the efficiency of the acquisition system; query systems that concentrate on the interface with the user (query language or command language) will emphasize communication; modeling systems such as those used in aircraft simulation and traditional data processing systems (bank transactions, statistical packages, scientific computing) will emphasize processing; and systems in which the user(s) and the data base are physically dispersed will emphasize transmission. Most components will be present in varying degrees in each of these system types.

Sources of Failure

While it may seem natural or trivial that a phone book or map does its job, the opportunities for failure in the information system are myriad. As mentioned above, one common source of error is in transposition. While the error may have limited consequences in an address (49 Harlan Drive may be close to 94 Harlan Drive), it could be more difficult to correct in the case of a phone number recorded incorrectly or a date (e.g., expecting to greet a visitor at the airport on the 12th, when the arrival date is really the 21st, because of operator error in the transmission of the message). One of the prime concerns in the design of an information system is recovery from failures. These failures may be physical (e.g., traffic light out, computer system down) or of content (e.g., transposition errors, obsolete data). As indicated earlier, various means of data verification, error detection, and error correction are used to combat content errors. Physical failures are handled by diagnosis and repair, as well as by backup systems and the development of more reliable technologies. The measures relevant here are mean (average) time between failures (MTBF) and mean time to repair (MTTR). A system averaging 85 hr between failures (synonymous with time "up") is "better" than one averaging 70 hr between failures. A system averaging 5 hr to repair (once "down") is better than one averaging 2 days to repair. Backup systems, especially those fully duplicated, reduce the MTBF and MTTR indirectly. The backup system does not prevent the failure of the primary system, nor does it hasten its repair; however, the effect of having two systems is that the entire operation "appears" not to have failed and the repair time is less crucial as long as it is well within the MTBF. A fully duplicated system is usually too expensive to maintain except for the most critical or profitable situations. An analysis of the relative importance of the system components can guide the allocation of resources to enhance reliability.

Reliability is one measure of the availability of the system, hence of the information produced (or coproduced) by the system. Another is the accessibility in terms of hours "open." This is especially a concern for systems that transmit data across distances that span different time zones. Having access to a data base in California during the working hours of 9
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to 5 (California time) is equivalent to having access from noon to 8 P.M. for a user on the East Coast.

The ideal system would be perfectly reliable, always accessible, error free, instantaneous in processing and retrieval, as well as economical, esthetic, and pleasant to use. The dictates of reality cause us to be satisfied with somewhat less.

Summary

In this chapter we have given a general overview of the activities involved in seeking, processing, and using information. The remainder of the text will be concerned with the concepts and skills required in each of the various stages, and in building information systems.

The text is divided into the following sections:

II. Data Collection and Analysis
III. Data Organization and Use
IV. Coding the Data
V. File Structures
VI. Data Retrieval
VII. Data Display
VIII. Human/Machine Communication
IX. Data Manipulation
X. Decision-Making and Problem-Solving

Recommended Reading

At the close of each chapter, other readings will be recommended. These will usually be secondary sources, e.g., other texts, since the reader is expected to be a novice in the area. These sources will lead to more advanced articles for the reader wishing to explore a given area in more depth.

The recommendations are particularly difficult for this first chapter, since there is little material on the treatment of information science as a discipline, and even less so on the paradigm of question-answering. Some work has been done in the areas of logic and artificial intelligence, of which the following may be of interest to the reader. There are also some compendia of articles on information and information science. These are not, however, introductory in nature.

Books on the design of information systems, usually automated, are more plentiful. Some representative works are:


Works on human information processing are:
