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On Systemness and the Problem Solver: Tutorial Comments

GEORGE G. LENDARIS, FELLOW, IEEE

Abstract—The main topic is the perceiving role played by the systems practitioner (SP) in the act of defining the system which is the subject of his problem-solving activities. A definition of system is given that makes explicit what perceptions must be made in order for one to assert that an

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The author is with the Systems Science Ph.D. Program, Portland State University, Portland, OR 97207, USA.
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object under observation is a system. The corollary ideas of properties-of-the-whole, suprasystem / system / subsystem, context, and (two-dimensional) multiple perspectives are discussed. The key advice is for the SP, during problem solving activity, to consciously adopt perceiving roles (perspectives), separately, at the supra-system, system, and sub-system levels, and to recognize that there is no such thing as an independent, objective perception of a system. The importance of the supra-system perspective to SP is improved ability to define context. The importance of multiple perspectives to SP is improved ability to consciously gather and organize a broad array of data about the problem. All these ideas are applicable to team problem solving.

I. INTRODUCTION

It is held herein (as an article of faith, based on years of experience on the part of the author and many others in the systems field) that a successful problem solver naturally incorporates in the problem-solving process ideas and procedures which have come to be known as the *systems approach*. Because certain systems ideas are deeper than they at first seem, considerable trial-and-error experience is often needed by the budding problem solver to acquire a good understanding of them. A particularly elusive one of these ideas has to do with the *perceiving role* played by the problem solver in the act of defining the 'system' which is the subject of his problem-solving activities. The purposes of this paper are 1) to present a definition of system that makes explicit what perceptions must be made in order for one to assert that an object under observation is a system, 2) point out certain corollary ideas important in developing a systems perspective, and 3) go through two examples to demonstrate the critical role played by the problem-solver's perceptions in defining a system. Some readers may prefer to read over the examples first (especially example 2 in Section IX), and then return to this part of the paper. Since perception is the key idea here, the first section discusses that topic.

II. PERCEPTION

Consider two different aspects of perception: 1) different people look upon the same situation and see it quite differently and 2) interpretation of sensory data is subject to illusion.

Any trial judge will attest to aspect 1. But even based on our own experiences, it should be clear that every individual looks upon the world through what might be called a unique set of perceptual *filters*, and these are determined by the individual's basic assumptions, expectations, desires, attitudes, etc., concerning the environment in which he is functioning. Which filter a person uses at any given time depends upon many factors, such as emotional state, physical state, and social role. These perceptual filters predispose the person to notice only selected pieces of data "out there" while neglecting others, and they also predispose how the selected data is processed and gleaned for meaning. The word *bias* is often used to represent these effects.

We illustrate aspect 2 via an example: consider the situation where one is driving on a long, straight road on a hot day, and at a distance ahead there appears what gives the driver an impression of a wet place on the road. However, when the driver reaches the place which had appeared wet, the road is found to be dry. We all know there is a so-called optical illusion involved here, one caused by certain interactions between heat, air, light, and observer. This example illustrates an interesting aspect of illusion: illusion cannot, per se, be corrected by knowledge (because illusion and knowledge are at two different levels of cognition.) In the above example, even 'knowing' the road is really dry does not change the illusion. The only thing the driver is able to do based on this knowledge is to make the decision (an act which is also at a different level than that of the original perception) not to believe the perception of wetness, and thus not to expect to find water on the road when the spot is reached. Only by changing internal processing of sensory data can one hope to achieve a different perception.

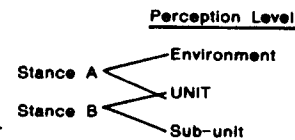


Fig. 1. Perceptual 'stances' associated with Statements A and B in definition of system. The system concept thus requires perception at three adjacent levels.

It is important for a systems practitioner to become aware (as much as is possible) of the particular perceptual filters he is using during a project. To accomplish this, it is useful to ask regarding his personal motivations: Why am I doing this? What is the purpose of my analysis? What am I attempting to achieve by my systems engineering activity? What questions do I want to answer? Which questions will I leave unanswered for another time, or for someone else? Only by giving proper attention to such questions will the investigator have a chance of making *appropriately biased* perceptions that allow him to declare a system, per the definition given in the next section.

III. DEFINING A SYSTEM

When we set out to *apply* the notion of system, we are not usually concerned with formal definitions *per se*. On the other hand, for a problem-solver-in-training, it can be useful to have a check-list type definition to use as a guide until a firm thought process is established.

Definitions occurring in our literature often include words like "... a system is a collection of parts operating together as a whole..." Such definitions, however, blur the fact that there are *two distinct* notions needing attention: a) there is a whole involved and b) there are parts that operate together to manifest that whole. For the present purposes, there is utility in a definition which separately addresses these two key features of the notion we call 'system':

A *system* is a) a unit with certain attributes perceived relative to its (external) environment, and b) a unit that has the quality that it internally contains subunits and those subunits operate together to manifest the perceived attributes of the unit.

The words "perceived," "attributes," "quality," etc., in Statements A and B entail a need for an observer to do the perceiving and to assess whether the stipulations in the statements are being satisfied. Indeed, an explicit observer role is required to assert systemness. Further, the observer role has to be carefully defined, for, as mentioned earlier, it is the case that different observers, each with a different perspective, will have different perceptions.

A key understanding which follows from the above definition is that three levels of perception are involved in the concept we call *system*. This comes about by noting that Statement A (re. unit, attributes, environment) requires a perceptual stance consisting of perception at two levels: that of the environment and that of the unit. Statement B also requires a perceptual stance consisting of perception at two levels: that of the unit and that of the sub-unit. These two stances have the unit level in common, resulting in a requirement for perception at three adjacent levels: environment, unit, and subunit.¹ (See Figure 1.)

A traditional assumption in classical scientific methodology was that the observer could be separated from the observed. In

¹Much of the research regarding systems over the past few decades has focused on the quality included in Statement B while *assuming* the quality mentioned in Statement A i.e., the researcher "automatically" defines the context and unit, and then focuses attention on the subunits, their relationships and joint actions, and how these relate to—or generate—the unit's attributes. Investigation of the relationships and the joint operation of parts while being mindful of the whole (as required in Statement B) has indeed resulted in important advancements; reports of this work constitute the bulk of systems literature during this period. From the applications point of view, however, it is important also to give explicit attention to defining the perception of the environment and the unit as required in Statement A.

the present context, though, it is important to acknowledge that 1) what is observed depends on the observer and 2) this dependence is fundamental. Such dependence is acknowledged in the well-known saying "Beauty is in the eye of the beholder." A similar statement in the present context might be "systemness is in the focus of the beholder." In this case the word beholder is expanded to include not only one who looks upon, but also one who thinks about, studies, and/or uses. The term *focus* is used here to connote that which is the subject of attention of the beholder. Thus what one means when pointing to something and calling it a system depends upon the role being played as a beholder, and this role must be consciously considered.

For example, suppose you are standing on a street corner and a person next to you points to a large brick apartment building across the street and says "there is an example of a system." Do you have enough data to know what he means? The answer is no. What role is this person playing during the act of perception: structural engineer, space planner, or sociologist? Clearly, for each of these hypothesized roles, different attributes-of-the-whole and different subunits to make up the whole are being considered.

IV. PROPERTIES OF-THE-WHOLE

A well-known statement in the systems literature is "The whole is greater than the sum of its parts." In order to properly understand this statement, its reader must be aware that different perceptual levels are required for thinking about the terms "whole" and "parts" in the statement. For the term *whole*, perceptual stance *A* (see Fig. 1) is required, whereas perceptual stance *B* is required for thinking about the term "parts." Indeed, this two-stance perception scheme must be invoked for the words "greater than" to have their intended meaning. The meaning is not the one we normally understand when the algebraic expression $x > y + z$ is read. Here there is an explicit assumption that items from the same domain are being compared (apples with apples). In the statement "whole is greater than..." apples are not being compared with apples. The words "greater than" are used to bridge two *different* domains (perceptual levels) and allude to the fact that certain attributes of the whole (perceived via stance *A*) cannot be deduced solely on the basis of observations made while in perceptual stance *B*. The reference here is to a fundamental property of systemness: the whole (unit, in the present terminology) has attributes which are intrinsic to the *joint operation* of the parts, and not to the parts individually. Thus, by virtue of joint action, the parts are able to manifest properties of the whole which are perceivable only by going "up" a perceptual level, hence the words "greater than."

A well-known example of this is the water molecule, whose subunits are the oxygen and hydrogen atoms, and these subunits are related in such a way as to jointly express properties-of-the-whole which can be expressed by neither atom individually (e.g., wetness), nor could be deduced by a study of the two atoms individually.

To demonstrate that there is an essential difference between the properties of the whole and the properties of the parts consider the mechanism we all know as a (mechanical) watch. Let there be a table with a collection of gears, springs, etc., strewn about on its surface, and a beholder who is naive about the idea of watch. There is much this beholder can learn about each of the parts, using a number of known measurement and testing techniques. But, there is nothing intrinsic to the parts themselves which will allow the beholder to deduce what the parts can do together when assembled according to what we (the story tellers) know as the organizing principle of a watch. The property-of-the-whole known as "tells time" is not intrinsic to the parts, but, rather, to the *collection* of these parts when they (by their *joint operation*) are *expressing* this attribute (i.e., after the parts are assembled according to the defining relations, the spring is wound, and, a starting impulse has been applied.)

Thus there are two aspects to the "The whole is greater..." statement cited earlier: 1) there is no way for an observer to deduce the attributes-of-the-whole by studying the parts and their individual operation, and then somehow "adding" these up; and 2) the parts, when jointly operating according to some organizing principle, can collectively do something which is "greater" than a simple collection of their individual un-coordinated operations.

Consider the watch again, and let us make two more observations. 1) Only at the instant when the attribute we have called "tells time" begins to be expressed can we say the above described collection of parts is a system. 2) Remove any part, and the collection ceases to operate as a watch: this is true of each part, so no part is more "important" than another. So long as each part is doing what it was designed to do, and operating according to the stipulated organizing principle, the system is, and each part can be said to be the watch attribute in expression.

How does the practitioner go about deciding whether the requirement "operate together to manifest..." in Statement B is being met? To guide our thinking via terms in our everyday vocabulary, we could assume the perceptual stance required by Statement A and use a term such as "purpose" (an attribute of the unit in its environment), or, we could assume the perceptual stance required by Statement B and use a term such as "organizing principle" (that which guides the interaction of the sub-units.) Using this vocabulary, we would ask, how can one tell when a collection of elements is functioning to fulfill some purpose and/or according to some organizing principle? Does one perceive, or think in terms of, the whole first, and then give attention to the elements which together operate to manifest that whole? Or, does one perceive the elements singly in some way until their collective functioning is "noticed?"²

As already mentioned, this paper is oriented to the problem solver. By definition, the existence of a problem implies a beholder with some norm in mind, and a state of affairs existing which is sufficiently different from that norm to warrant the beholder's attention and, presumably, action. The norm is here considered to reside at the level of the whole. Therefore, for such a problem solver, a conception of the whole will generally precede attention to the parts.

V. SUPRASYSTEM / SYSTEM / SUBSYSTEM

Every system has a subsystem.³ Every system is an element of a suprasystem. What do these statements mean? To answer this, we again make recourse to the notion of beholder/perceptual filters.

We first develop some terminology for the rest of the paper by defining three beholders, and ascribing a special focus to each:

²There are two words in the systems literature which I suggest can be usefully applied as follows: *Wholism*: to represent what the beholder (who has the perceptual stance required by Statement A does as he perceives the *unit* and its attributes-of-the-whole in its (external) environment. *Holism*: to represent what the beholder (who has the perceptual stance required by Statement B does as he perceives that there is a collection of subunits operating together as a whole. (This implies a statement like: the beholder is *mindful of the whole* as he attends to the parts and their relationships.) In the wholism process, the beholder acquires the appreciation of the whole without recourse to parts, but rather by a focus which perceives the whole as a whole, in its environment. In the Holism process, the beholder is mindful that there is a whole while attending to the parts and their relations, and may acquire an appreciation of this whole as a Gestalt, the latter incorporating his observations of the parts and their interactions. Thus, the perception we call *system* requires the beholder to accomplish both a *Wholistic and Holistic* appreciation of that which is to be declared a system. Usage of the terms "wholism" and "holism" (or wholistic/holistic) has alternated in the literature. The usage here is a reversal from what I used in an earlier paper, and is now more in keeping with the original coinage of the term "holism" by Smuts, the term '*holon*' by Koestler, and some recent systems literature.

³According to some theories, at very microscopic levels there are elementary units which cannot be further reduced. If so, we allow this as a stopping point. Similarly, in the other direction.

Perceptual Levels ↓	(Beholder M) (System M)	(Beholder S)	(Beholder P) (System P)
	Supra-System	SYSTEM S	Sub-System
A	Environment		
B	★ UNIT	Environment	
C	Sub-unit ← ★ UNIT	★ UNIT	Environment
D		Sub-unit → ★ UNIT	
E			Sub-unit

Fig. 2. Focal level (★) of Systems Practitioner shifts as he adopts roles of Beholder *M*, Beholder *S*, and Beholder *P*. Entries are names given to perceptual levels according to Beholder roles. (*M* stands for Meta-system, a synonym for suprasystem, and *P* stands for part, a proxy for sub- in this discussion.)

Beholder *M*, Beholder *S*, and Beholder *P* (see Fig. 2). Beholder *M* will have a focus which perceives an environment, unit, and subunits working together... so as to define System *M*. Beholder *S* will have a focus which perceives one or more of the subunits in System *M* as a unit, perceives subunits working together within this unit, and uses the rest of System *M* as its environment. Beholder *S*'s system is called System *S*. Finally, Beholder *P* will have a focus which perceives one or more of the subunits in System *S* as its unit, perceives subunits working together within this unit, and uses the rest of System *S* as its environment. Beholder *P*'s system is called System *P*. In Fig. 2, the term "focal level" is used to refer to the middle of the three perceptual levels required for perception of a system; i.e., the UNIT level.

We can now describe how the terms *subsystem* and *supra-system* are used.

SubSystem: From the perspective of Beholder *S*, without any additional information, Beholder *P*'s System *P* is simply one or more of System *S*'s subunits (in relationship with System *S*'s other subunits.) But, when provided the information by Beholder *P* that this subunit (or, these subunits, taken together) qualify as a system, Beholder *S* may then call it a subsystem. The same is true for Beholder *M* vis-a-vis Beholder *S*'s System *S*.

Supra-system: From the perspective of Beholder *S*, without any additional information, Beholder *M*'s System *M* is environment. But, when provided the information by Beholder *M* that this environment can be perceived as a system (with the unit of System *S* being a subunit of System *M*), Beholder *S* may then call it a supra-system of *S* (or, as often called in the literature, a meta-system of *S*.) The same is true for Beholder *P* vis-a-vis Beholder *S*'s System *S*.

In general, for a beholder to use the term *subsystem*, information from a beholder one level down is needed. Similarly, to use the term *supra-system*, information from a beholder one level up is needed. With this understanding, the initial two statements of this section can be restated as follows: Relative to a Beholder *S* who perceives a System *S*, 1) one can always define a beholder role whose focal level is the next level down from that of Beholder *S*, and such that this beholder perceives a system within or among System *S*'s subunits, thus yielding a subsystem relative to Beholder *S*; and 2) one can always define a beholder role whose focal level is the next level up from that of Beholder *S*, and this beholder perceives a system such that System *S* is one of the subunits, thus yielding a supra-system for System *S*. These statements are held to be true for any Beholder *S* perceiving any System *S*.

VI. CONTEXT

Up to this point, we have used the term *environment* without any special clarification. Generally, environment is said to be everything which is not included as part of the perceived unit.

For the practitioner's purposes, however, this definition is not adequate. The practitioner is well aware that in the act of the required perceptions, the beholder brings considerable collateral knowledge to the task, and is thereby able to make more manageable an otherwise infinite environment. In this process, the beholder may, for example, distinguish certain aspects/components of the environment as being relevant to the task at hand, and having done so, the term "relevant environment" is used. In problem-solving situations, this process is one of providing a context for the practitioner's activities. Indeed, proper formulation of context is crucial for successful problem solving.

A common operational means for establishing context is to define a supra-system relative to the system in the beholder's focus. This requires defining a Beholder *M* role according to the needs of the problem solving situation. The resulting supra-system definition will identify which other units in System *S*'s environment are considered its companions as subunits for the supra-system, and, what the relationships are among them. Clearly, more than one supra-system can be defined for each system (each corresponding to a Beholder *M* with a different perspective, e.g., see example 2 in the Section IX.) Each such supra-system provides a different context for the system in Beholder *S*'s focus.

In general, each system level provides a context for the level(s) below. It is useful for the problem solver to keep this principle consciously in mind as the chain of levels is traversed up and down during the solution process.

Context is probably the single most important notion for the systems practitioner to keep consciously in mind during the problem-solving process. It is the information that provides the practitioner with a basis for defining properties-of-the-whole of the system to be designed, or, for understanding those of systems being analyzed. The attributes of the unit whose perception is required in Statement A of our definition can only have meaning relative to a defined context. The systems-practitioner's problem-solving activities are broad and varied; they include: problem definition, defining of values and criteria for decision making, synthesis of potential solutions, analysis, optimization, decision making, etc. All of these require close attention to the context within which they are carried out.

Context may be looked upon as having a similar relationship to the beholder's "outer world" as does perspective to his "inner world."

VII. MULTIPLE PERSPECTIVES

It is said that the human mind can only deal with a relatively small number of independent pieces of data at one time, but if data are chunked together in appropriate ways, the mind can perform higher order abstractions, and these in turn can be chunked together, with successive abstractions, until an entire complex situation is encompassed. The systems approach addresses this property of the human mind by providing strategies for the data gathering, chunking, and abstracting process. The one discussed here is called *multiple perspectives*. In this strategy, the practitioner is advised to role-play a variety of perspectives in the process of attaining an understanding of a complex situation.

It is time to be explicit about the use of the term "perspective." It is here used to connote a particular role player's *perceptual filters* used in a given problem-solving situation. Thus, the multiple perspectives suggestion might be said as follows. Assume the role of a given actor in the situation; then, according to the perceptual filters attendant with that role, characterize the environment and the attributes of the unit being perceived in that environment; next, identify/characterize the subunits and the relationships among them that allow them to comprise the unit and express its attributes; this accomplishes one patterning, or chunking, of the problem situation. Following this, adopt the role of *another* actor in the situation; then, according to the perceptual filters attendant with this new role, repeat the above process.

System Level ↓	R-1	R-2	R-3	R-4
Supra-Supra-				
Supra-				
System S				
Sub-				
Sub-Sub-				

Different Roles

Fig. 3. Map of perspectives to be adopted by systems Practitioner as he adopts various roles.

Based on the previous discussion, it follows that the patterning (system) defined from the two different perspectives will be different. This process should be repeated a number of times, where the number and type of perspectives depends upon the particular situation. As the different system definitions are completed (each comprising one "chunk" of information), the practitioner has the opportunity to internally process these and attain a fuller understanding of the problem situation being studied—or, at least, to separately address critical aspects of the situation in a conscious and organized way. We are now ready to give the most important advice of this paper.

It is desirable for a systems practitioner, let us call him Beholder SP, to adopt the roles of Beholders *M*, *S*, and *P* at least during the problem definition phase of a problem-solving process. Adopting the role of Beholder *M* allows Beholder SP to acquire an important understanding of the context in which System *S* operates, as well as becoming explicitly aware of the range and substance of the requirements the suprasystem places upon System *S*. Further, adopting the role of Beholder *P* allows Beholder SP to better understand how tightly the parts interact with one another, and to better understand possible options for improvements and/or reconfigurations that may be useful during the problem-solving process. Fig. 2 makes clear that in the process of adopting the three suggested beholder roles (three system levels), Beholder SP is obliged to function at *five adjacent perceptual levels*.

So far, the discussion has been focussed in the "vertical" dimension. It is to be noted, however, that since more than one suprasystem can be defined for each system, there is also a "horizontal" dimension to our considerations (see Fig. 3.) In this dimension, each suprasystem definition will depend upon the beholder role chosen for that level; therefore, continuing the advice of the previous sections, it is eminently useful for Beholder SP to define qualitatively distinct Beholder *M* roles and follow through the resulting suprasystem definitions and their implications to the subject system. After having done this, (back to the vertical dimension) it is often useful to step up to the suprasupra level to discover what additional insights might be gained which subsequently contribute to understanding the context(s) and the system being considered. Similarly, it is useful to make a conscious effort to define/describe the system's properties-of-the-whole from the vantage point that these are to provide a context for the component subsystems. This, too, should be done from the perspective of several different beholder roles (more horizontal dimension). These strategies are extensions of the one given previously, and they often open up the practitioner to a breadth of perception not otherwise forthcoming.

A key difficulty in all of these strategies is the accuracy of defining the separate roles and attendant perceptual filters to be simulated. For each of these perspectives, the systems practitioner needs to develop a clear understanding of such issues as 1) how to characterize the environment as a context, 2) where does the environment stop and the unit begin, 3) what is the interac-

tion of the unit with its environment, 4) how to characterize the properties-of-the-whole of the system being defined, and 5) what is it that the systems practitioner wants to achieve by taking the time and energy to define the system in the first place?

The entries for the table in Fig. 3 cannot be specified ahead of time. Rather, each slot is a place holder, and what goes in each slot depends on which one is chosen as the starting point. For example, let the *unit* at the System *S* level serve as the reference point. Assume that properties-of-the-whole of the unit are the entries in the System *S* row of the table. What properties a beholder perceives of the System *S* unit depends on the perceived context, and this depends on the particular Beholder *M* role adopted, as the latter dictates the definition of the suprasystem. (See example 1 in the next section for an example of the striking differences possible.) Assume that the entries in the subsystem row of the table are a list of the subunits and their important relationships. It is clear that these too might be different, depending on the properties-of-the-whole listed in the next slot up in the column, and this depends on the particular Beholder *M* role adopted for the slot above it. These comments are extendable upwards and downwards, so this is not a fixed table; hence, the beginning statement above that the entries for the table cannot be specified ahead of time. (In some recent literature, the name "multiple perspectives" has been applied mainly to the horizontal dimension of Fig. 3, without specifically applying that name to the vertical dimension.)

A person new to the arena of complex problem solving may complain that the (two-dimensional) multiple perspectives suggestion given above appears to be adding a complexity of its own. Not so. The assumption here is that the "reality" being investigated by the systems practitioner is rife with complex relationships, and that there is so much data that the practitioner would have no chance of comprehending it without some strategy for an organized inquiry. The multiple perspectives strategy accomplishes two purposes: 1) offers an approach for the problem solver to consciously consider and keep track of the multitude of data and relationships that affect a given problem situation and 2) nudges the problem solver to perceive the problem situation from perspectives which often are not taken into account.

VIII. TEAM PROBLEM SOLVING

The assurances of the previous paragraph notwithstanding, the cognitive capacity of an individual human being does have its practical limitations. Therefore, one usually finds a *team* of people working on systems problems beyond a certain scale of complexity. In fact, this situation tends to be the rule rather than the exception. Now, the beauty of the systems concept can be brought to bear: to apply all of the above descriptions of and advice given for the "systems practitioner," the reader may use the simple expedient of considering the problem-solving team as a system and the team as a unit is to manifest the properties of the systems practitioner and is to follow the advice given above. In a team, it is not required that one individual have the cognitive capability to do all the role playing called for, nor to integrate all of the myriad of details needed. Rather, these are accomplished by the joint effort of the individuals in the team, functioning as a unit. The trick, of course, is for someone to select people with an appropriate set of skills, experience, and expertise, and to manage them in a way that the desired "systems practitioner" attributes are manifested. All of the concepts and procedures given above in the guise of speaking about a single systems practitioner can serve as guidelines for the manager of the team to co-ordinate the inquiry and design process, to select the people and resources for the team, and to guide the activities of the individuals so the team will manifest the desired attributes. (There are, of course, other aspects to managing teams of people not addressed in these statements.)

IX. LARGER EXAMPLES

The greatest difficulty in giving examples for a discussion such as this is describing the tremendous amount of background knowledge/information that the beholder needs to have in order to make the necessary perceptions. For example, in an earlier section I asked the reader to consider the mechanism "we all know as watch." If the reader were a just-arrived visitor from Mars, I could not get away with this statement. Ponder for a moment the amount of background knowledge required for a person to perceive the attribute we called "telling me time." What is time? What observations, study, and inferences would be required for the new beholder to relate the cycles of the sun appearing and disappearing with the cycles of the lines that move around the outer surface of the unit? What are those markings on the surface? What is that noise? What is the purpose of the noise? Etc., etc. There is much a beholder must learn of the environment before it is even possible to have the linked perceptions required in Statements A and B in our definition of system. This is true of the systems practitioner (Beholder SP) whenever entering into a new problem-solving situation. Similarly for the examples to be introduced next.

I make the assumption that the reader has appropriate experience in our culture so the following words will elicit (in at least a fuzzy way) the background knowledge needed for our discussion: airplanes, airports, air space, air traffic control, terminal, surveillance, radar, transmit, and receive for the first example, and urban area, large real estate development, apartment building, and design for the second example.

A. Example 1—Air Traffic Control

Let Beholder SP adopt a focus to discern a system called "air traffic control radar." While in perceptual stance *A*, Beholder SP could adopt a *functional* perspective from which the radar unit is characterized by the functions transmit, receive, process, etc. While in perceptual stance *B*, Beholder SP could adopt an *engineering-function* perspective from which he might segregate the electrical components comprising the radar unit into subcollections that perform the above functions (e.g., transmitter, receiver, processor, power supply, etc.) These two perceptual stances, of course, are applied at the same system level (e.g., corresponding to the middle column in Fig. 1.)

The words "air traffic control radar" can only have meaning in an appropriate context (suprasystem), such as "terminal area traffic control system." Hence, our Beholder SP must adopt a perspective at this suprasystem level at least once during his problem-solving activities. A suprasystem for the suprasystem (hence, a suprasupra system for the radar unit) might be the 'national air traffic control system,' etc.

One of the functions (properties-of-the-whole) of the terminal area traffic control (supra) system is surveillance—i.e., detect, track, identify, and give advisories to all aircraft in the terminal air space. The suprasystem's properties-of-the-whole include: working in the presence of rainstorms, handling high traffic densities at 6:00 p.m. most days, etc. To perceive these, Beholder SP will have to assume a Beholder *M* role, and adopt the perceptual stance of Statement A. To perceive the subunit we above called the air traffic control radar, Beholder *M* will have to adopt the perceptual stance of Statement B. From this stance, additional subunits and relations among them can be perceived, such as, air traffic controllers and the regulations which govern their activities.

Once we introduce people (air traffic controllers) into the system description (recall, we are now at the suprasystem level of the previous two paragraphs), another perspective is soon called for. When a system has more than just a few people in it, they will coalesce into, form, or evolve some sort of organization—usually reflecting (hardware) system structure and function. The resulting organization of the people involved becomes an integral aspect of the relationships among the subunits that allow them to

manifest the properties-of-the-whole of the system. This organizational aspect may thus have overriding effects on future attempts to introduce modifications into the system structure. Thus a systems practitioner must learn to view a system from an *organizational* perspective as well.

There are other candidate perspectives. For example, different suprasystems of the given system may require that it fulfill purposes that are sometimes conflicting. In the "terminal area traffic control system" example, the purpose is to regulate the flow of air traffic so as to minimize the likelihood of collision and/or accident while maximizing the flow (or some such objective function). But, the Defense Department uses these same traffic control centers as Ground Control Intercept centers in the event of air attack against the U.S. mainland. The air defense purpose is to vector defensive aircraft toward incoming enemy aircraft—i.e., to *promote collisions* (in a controlled sense) at *any cost*. The unit and the structure of its component subunits is essentially the same. But, it is now part of a different suprasystem and hence has a different environment/context. In this new context, a different purpose (property-of-the-whole) is imposed. It is important that the analyst not overlook any of the important suprasystems of the system being studied, as they provide the means for discovering the various requirements to be satisfied by the given system. From this example, another perspective type to add to the repertoire is that of *mission* perspective.

As was alluded to earlier, Beholder SP might adopt a perspective which looks for subunits within a unit according to the unit's natural physical (hardware) structure. Using the same strategy, a computer program might be decomposed into routines, sub-routines, statements, etc., in accordance with its natural logical software structure. This perspective might be called *structural* perspective. From this perspective, the subunit definition is basically provided by the original designer. Sometimes one is led to believe that this structural perspective is the systems perspective. As we have shown, the systems perspective is far more than just this.

B. Example 2—Architectural Design

For this example, the systems practitioner is an architect, and the task is to design an apartment building. Assume this building is part of a large development, but the architect's focus is such that the apartment building is the system. To the real estate developer, the "large development" is the system. The developer perceives his system as having certain attributes in its environment/context (the urban area), and has defined an array of subunits related in such a way as to manifest the desired properties-of-the-whole. The apartment building is to be one of this system's subunits. For the architect, the developer's system is the key suprasystem; it provides the context for his design efforts, and is the environment in which the attributes of the apartment as a unit are specified and understood.

There are, in addition, a variety of other suprasystems of which this apartment building will (simultaneously) be a subunit. For example, the urban area's electric distribution system, water distribution system, garbage disposal system, transportation system, mail delivery system, cable tv system, etc. At some point(s) in the process, the architect needs to assume a perspective appropriate to each of these suprasystems to arrive at acceptable design parameters for the apartment building. Relative to Fig. 3, this means that a separate column is created for each of these suprasystems. Using each of the associated perspectives, the slot for unit attributes is filled in in each column. When finished, the collection of attributes in the System *S* row are the design parameters referred to.

Once the architect has internalized an understanding of the context for which the design is being made, he is able to focus on defining the "style" and other properties-of-the-whole for the apartment building. The attention is on creating a design that is

aesthetic and at the same time meets the requirements of the suprasystem(s).

We pause to remind the reader that based on prior experience with similar design situations, the architect will do many of the tasks discussed here rather "automatically". As a repertoire of successful patterns is built up, the architect uses these without having to give conscious consideration to the basics. However, in novel situations, where the prior patterns do not fit, the architect again must revert to more detailed consideration of various aspects of the design—and this means adopting the perspectives appropriate to the various systems that exist simultaneously in the finished product (e.g., plumbing, electrical, structural, sociological, etc.).

The developer will likely stipulate general quality requirements (e.g., luxurious vs. affordable, large vs. small, etc.) for the apartment building. These translate down to properties-of-the-whole of the individual apartment units, and provide some guidance to the relative placement of the various apartments in the building. The architect will, at some point, conclude the first pass at defining the system called apartment building: environment, unit, and subunits with their relationships. The architect must eventually change focus, so that now the individual apartment becomes the system. The results of the previous pass are used as properties-of-the-whole of the apartments, and now attention is given to designing the subunits comprising this new unit. While creating this design, the architect needs to adopt perspectives appropriate to systems such as the following: social system that will live in the apartment; structural system; plumbing system; and electrical system. Eventually, design specifications are created that do not violate strictures from any of these perspectives. For example, when deciding where to place the kitchen, bathroom(s), and laundry facilities, the architect must at some point explicitly adopt the perspective appropriate to the plumbing system. Cost savings are realized by having the plumbing in common walls; the drain lines must have a minimum slope; etc. These place definite constraints on how the various rooms are placed relative to one another. At the next system level up (the apartment building), similar considerations place constraints on the relative placement of the apartment units within the building, and of kitchen/bathrooms/laundry of one apartment relative those of other apartments.

To some degree or another, the architect must give similar consideration to all the important sub-systems of the apartment building. The reader is invited to think through some of the more common ones.

The purpose of citing the above examples was to illustrate the need for a systems practitioner to consciously adopt multiple perspectives, both "vertically" among system levels, and "horizontally," through an appropriate set of companion systems and/or role players. This suggestion is made to the new systems practitioner to use as a guide through complex problem-solving situations; as it is successfully used, the methodology should become internalized, and thus not need too much conscious consideration. Repeating an earlier statement, we believe that successful systems practitioners do these things automatically.

Let us again emphasize an important point. As stated earlier, the particular set of perceptual filters being used at anytime by a beholder influences (determines?) his perceptions. This is true as he adopts the role of beholder at the suprasystem level to define a context; as he adopts perceptual stance A to perceive a unit with attributes in the defined context; as he adopts perceptual stance B to perceive the collection of parts which are operating to manifest that unit; and, as he adopts the role of beholder at the sub-system level, for which the original system now defines the context, and the process repeats itself (cf. Fig. 2). Thus, what the beholder declares as a system depends very intimately on the beholder himself.

There is no such thing as an independent, objective perception of a system.

X. SUMMARY

The two separate aspects of system included in the definition as Statements A and B, and the ideas of properties-of-the-whole, suprasystem/system/subsystem, context, and (two-dimensional) multiple perspectives are fundamental for the systems practitioner to understand as problem-solving tasks are carried out.

It is particularly useful in practice for the systems problem solver to understand that beholder roles at (at least) three contiguous system levels must be adopted—and this implies five contiguous perceptual levels (Fig. 2). Further, different beholder roles must be adopted *within* each system level (Fig. 3). These are all fundamental to what we call the systems approach.

It is important for the problem solver to keep in mind that he cannot extricate himself (totally, at least) from the systems he declares. Two aspects are key here: the perceptual filters of the beholder determine the beholder's perceptions and that *systemness is in the focus of the beholder*. There is no such thing as an independent, objective perception of a system.

As was hinted at in the examples, a key ingredient of the systems approach is for the systems practitioner to *remain mindful of the whole* while going about his business; and, using the systems approach, the systems practitioner is in a better position to gain an appreciation of, and to deal with in an organized way, the deep interrelatedness of virtually everything involved in a problem situation.

Finally, though the expository style has been to refer to the systems practitioner (problem solver, Beholder SP) as an individual, all that has been said can be applied to the more usual *team* involved in systems problem solving—where the team as a *unit* is to manifest the discussed 'systems practitioner' role.

ACKNOWLEDGMENT

I take the unusual step in this paper of citing no references. My reason is that in the over 25 years of my involvement with the systems field, I have read many papers and books and have personally spoken with many of the authors. I certainly have been influenced by all of them, and I here acknowledge that. What I offer here is a personal distillation of what seems to me a useful teaching to those who attempt to use the system concepts in their problem-solving activities. No single item I include here is likely to be new; and yet, my own way of organizing the thoughts, what is said, and what isn't, constitute a unique perspective. I do wish to thank the (anonymous) referee who suggested the application I included as Example 1 in Section IX and the questions I included in the last paragraph of Section II.

NOMENCLATURE

Beholder	One who looks upon, thinks about, studies, and/or uses.
Context	Information regarding the environment that provides the basis for a beholder to define and/or understand the attributes of a unit.
Environment	Everything which is not included as part of the perceived (system) unit.
Focus	That which is the subject of attention of the beholder.
Focal Level	The perceptual level of the beholder at which the unit of the system is perceived.
Function	An attribute of the (system) unit in its environment/context.
Holism	What the beholder who has perceptual Stance B does as he perceives the subunits operating together as a whole. (The beholder is <i>mindful of the whole</i> as he attends to the parts and their relationships.)
Multiple Perspectives	A strategy to role-play a variety of perspectives in the process of attaining an understanding of a complex situation.

Perceptual Filter	Connotes that processing of sensory data within a human being which predisposes the person to "notice" only selected pieces of data from the environment while neglecting others, and also predisposes how the selected data is processed and gleaned for meaning. Choice of the particular "filter" used by a person at a particular time depends upon factors such as emotional state, physical state, and social role being played.
Perceptual Stance	See Fig. 1.
Perspective	The perceptual filters of a specified beholder role.
Purpose	An attribute of the unit (property-of-the-whole) in its environment/context.
Statement A	A unit with certain attributes perceived relative to its (external) environment.
Statement B	That unit has the quality that it internally contains subunits, and those subunits operate together to manifest the perceived attributes of the unit.
Subsystem	A term used by a beholder for a partial collection of the subunits in a system he has declared, when that partial collection is declared a system by a beholder whose focal level is the next perceptual level down from the focal level of the subject beholder. (cf. Fig. 2)
Subunit	An entity that is perceived to be a component part of that entity perceived as the unit of a system.
Suprasystem	A term used by a beholder for the system declared by a beholder whose focal level is the next perceptual level up from the focal level of the subject beholder, and, the subject beholder's system unit is a subunit (or, partial collection of subunits) of the referenced system. (cf. Fig. 2)
System	Statement A and Statement B
Unit	That entity which is the subject of attention (focus) of a beholder who is in perceptual stance <i>A</i> .
Wholism	What the beholder who has perceptual stance <i>A</i> does as he perceives the unit and its attributes-of-the-whole in its (external) environment.