

This brings us to that stage of the design process which can be considered the middle zone of the process, where the verbal information of the analytic phase is evolved into the visual information of the synthetic phase. This transformation from verbal to visual information is characterized by series after series of sketchy expressions best described as "doodles." If we consider design as a communication activity, these doodles—their verbal predecessors and their visual successors—are tools of communication which the designer uses to continuously record developing ideas. In the case of the single designer working on a particular design problem, these records are maintained so that ideas may be communicated accurately back to the designer who originally recorded them. In the case of a team of designers working on a common problem, the records serve as conversational aids (visual and verbal) among the designers involved.

Conceivably, the sophistication of the design solution depends on the sophistication of the communication tools used. The tools in current use in the initial verbal and the final visual stages of the design process are reasonably well developed, i.e., the relevant vernacular and the working-drawing systems. However, the efficient handling of ideas generated as doodles is often difficult for a single designer because of his lack of recall, and proves to be impossible for a team of designers since each member of the team will have a different doodle "style." Actually, collaboration at this stage of the design process is most likely not even considered. It follows, then, that there exists a need for a common language or notation system which would allow design ideas to be expressed and recorded in a consistent way. My interest in a diagrammatic language for design stems from involvement with decomposition computer programs for the analysis of design-problem structure and the use of constructive diagrams as part of this design methodology.¹ It is the contention of my thesis that there exists a set of diagrammatic elements which designers subconsciously use as part of their thought patterns which can be identified and formalized into a grammatical structure as a diagrammatic language for design. Research to date has been concerned with the following five stages:

1. Design methods and the design process in general.
2. Diagram systems in current use in other disciplines.
3. Artificial languages and their compilers.

4. Identification of the elements of the design language and the subsequent grammatical structure.
5. Delineation of possible visual forms of the notation elements.

The next stage of the project will be:

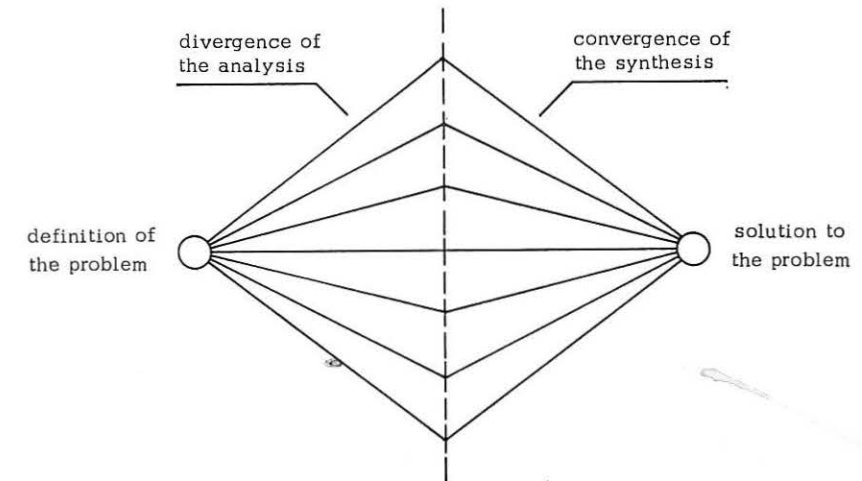
6. Experiments in the use of the design language.

Full development of the language will be an evolutionary process resulting from its use. This paper, therefore, constitutes a preliminary report on a continuing project and is presented at this time to draw comments and criticism from designers and educators.

The Design Process

It may be helpful at this point to look at some conceptual models of the design process in order to see where this diagrammatic language could be used. Figure 1 shows a very simplistic and familiar conception of the design process. The starting point is the definition of the problem; the endpoint, its solution. With respect to the discussion above, the area of divergence is essentially verbal and the area of convergence is essentially visual. The area of overlap is the realm of the diagrams which supports the transition from verbal to visual.

Figure 1. Fan model of the design process.



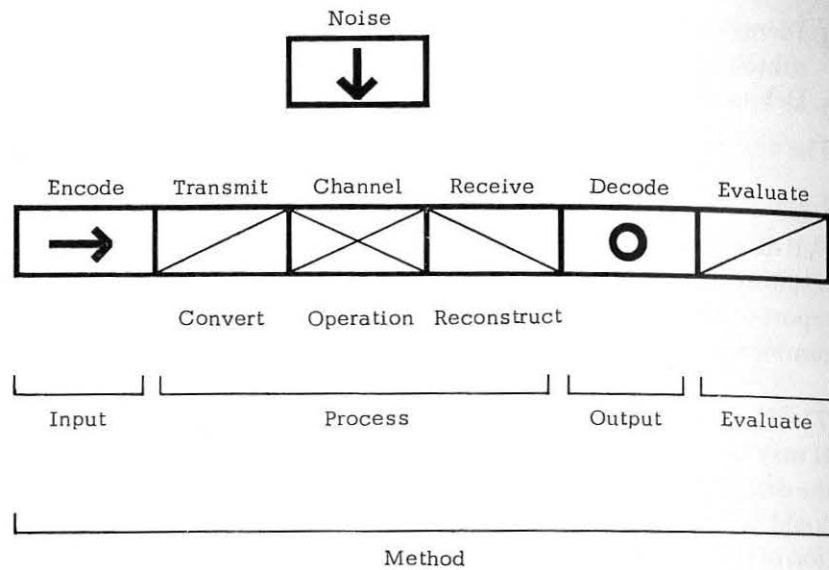


Figure 2. Shannon and Weaver model of communication.

Figure 2 is a more complex model adapted from Shannon and Weaver's model of communication.² It can be considered in two ways: first, as an overall model of the design process in the sense of a problem definition (input), designer activity (process), and solution (output); second, as a model to be duplicated end-to-end as many times as there are identifiable stages of communication activities in the design process. For instance, the designer may "encode" thought and transmit via a "channel" of a sketch on paper to be "received" by a design partner or consultant or himself at a later time. "Noise" could be anything that would in any way deteriorate the quality of the intended message, from wrinkling the paper to the designer's lack of talent as a draftsman. Relative to diagrams as a communication activity we must consider such questions as: What is the encoding and transmitting process? What kind of channel is used? What is the receiving and decoding process? What kind of "noise" will be present during the process? How is the result evaluated? For the sake of simplicity the discussion will be limited to a handwritten notational system using suitable two-dimensional surfaces as media.

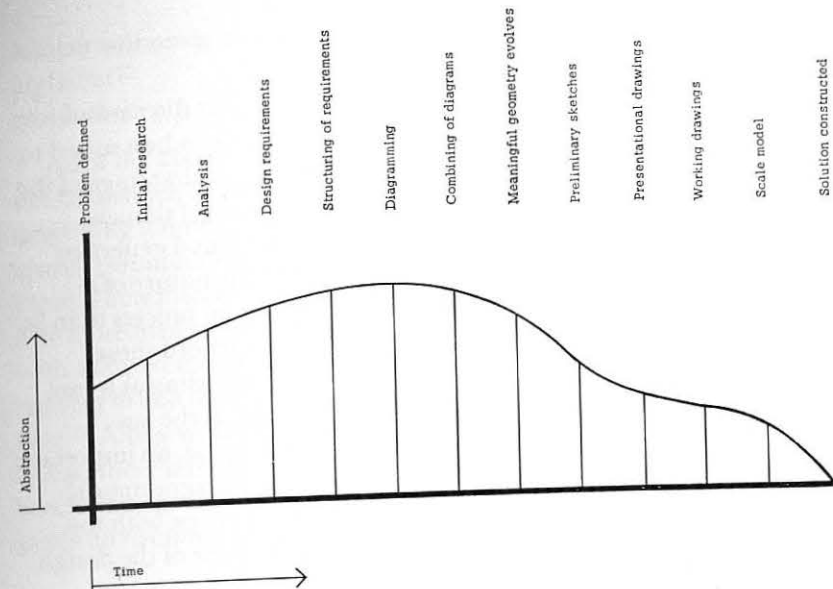


Figure 3. The design process: abstraction vs. time.

Figure 3 shows a still more complex model: a graph of the overall elapsed time of the design process divided into the sequence of the various phases or modes of expression associated with the design process. The vertical dimension indicates degrees of abstraction (units unspecified). For example, preliminary sketches are more abstract than a scale model. Zero abstraction is, of course, the final solution fully constructed and ready for use. With reference to the discussion above, we can say that the area of the curve to the left of the peak is the analytic phase of the process and the area to the right is the synthetic phase. The important point is that the higher the degree of abstraction of a mode of expression, the more manipulatable it is in terms of human time and energy expended relative to the form of the final solution. For example, a single line as an element of a diagram may represent the basic configuration of an entire architectural space, whereas a single line as an element of a working drawing may only represent the surface of a single wall. Thus, in terms of designer time and energy, the removal of this single line in a diagram might remove the entire wing of, say, a school building, whereas this same amount

of line removed from a working drawing might only mean the removal of a single partition.

The reason for the different modes of expression for the various stages of the design process is that each of these modes is best suited to record the type of human thought being generated at that stage of the design process.³ Herbert Simon refers to the elements of thought (parameters of memory) as "chunks." The human mind generates these chunks at reasonably constant intervals.⁴ If the nature of a chunk of thought is different at one stage of the design process than at another, the mode of expression (notation) used to record these chunks as they are generated must be capable of recording at a rate commensurate with interarrival time of the chunks. If the lag between chunk speed and notation speed becomes great, an important chunk may be forgotten before it can be notated. A diagrammatic language must provide the notation system that can cope with the relational type of thought produced at this middle zone of the design process.⁵

Diagrams and Language Systems

If we are to devise a diagrammatic language and notation system for design, it would seem appropriate to survey similar diagrammatic systems in other disciplines. Unfortunately, space does not permit a discussion of any of these here.

music notation⁶

Labanotation—dance notation⁷

Motation—language of motion⁸

sequence experience notation⁹

symbolic logic

electronic schematics

flowcharting of computer programs

Therbligs—industrial process notation¹⁰

architectural working drawings

proofreading notation¹¹

PERT charts—scheduling networks¹²

Blissymbolics—visual language¹³

aUi—language of space¹⁴

Proxemics—human interaction behavior notation¹⁵

Kinesics—human movement notation¹⁶

alphabet¹⁷

graph theory¹⁸

All of the above are visual systems containing a limited number of symbols which in various combinations and formats are capable of describing a limitless number of situations.¹⁹ In addition to the field of visual communication, traditionally associated with graphic design,²⁰ there is new interest in the use of visual languages as design tools.²¹ The more firmly established world of non-visual linguistics²² functions with a few elements saying everything there is to say. Basic English reduces to 800 the number of English words necessary for conversation.²³ Along with new inter-disciplinary research in environmental design there is interest in formulating a set of environmental descriptors for an agreement on terms in speaking about natural and man-made environment.²⁴

Diagrams as a Language System in Design

The design process is an evolutionary progression; an idea is refined continuously until the resulting form satisfies the initial objectives. It is a process that proceeds from the general to the specific and from the abstract to the real. It is a process of leveling and sharpening.²⁵ Once the analytic phase of the process is complete and the design objectives defined, the diagrammatic language will be employed to set down in a presentational visual way (as opposed to the sequential verbal methods of the analytic phase) the desirable relationships between the conceptual components. These relationships will evolve into ever more specific relationships that are defined by type and degree. The diagrammatic language must be both visual to show relationships, and mathematical to show degree of relationship.²⁶

Primitives and Grammar of a Design Language

Since the initial diagrams in the design process would express the desirable relationships specified in the design requirements, it seemed logical that the place to begin a search for the basic elements, or primitives, of the design language would be among available collections of design requirements by various designers for particular problems. Consider the following three design requirements which are relevant to three different design problems:

1. Urban mass transportation system: any pollution created by the transportation system must be contained and not be allowed to enter the environment external to the transit system.
2. Elementary educational facility: distraction factors external to an academic setting (such as a classroom) must be controlled so as to not disturb the students' concentration.
3. Residence: children in their play activities should not be subject to contact with vehicular traffic.

The notion to be abstracted from these three requirements is a common one: "protection." Protection is the desirable relationship that should exist between the pairs of parties named in each of the three requirements.

On a similar basis, the accumulated design requirements of seven different documented environmental design problems were searched. The average number of requirements per problem was approximately 100; approximately 200 notions were abstracted from these 700 requirements. Some notions occurred only once or twice, whereas notions such as "protection," "proximity," "access," and "control" occurred 10 to 30 times each. The distribution was not tabulated in this initial search. Redundant notions (such as "control" and "supervision") were eliminated until approximately 100 notions remained. A positive or negative relationship was identified between every possible pair, and a decomposition computer program²⁷ was used to identify subsets of highly interrelated notions. Analysis of the subsets revealed further synonymous ideas which were eliminated to produce a list of 50 notions (opposite), which may be considered as an attempt to see what the primitives of the design language might be.

These 50 primitives were, in turn, processed through the decomposition program and simplified further by observation and experiment to produce the structure shown in Figure 4. An initial attempt at defining the visual elements of the language is shown in Figure 5, where symbols and mnemonics have been substituted for the words in the structure of Figure 4.

The structure of this "grammar" proceeds downward from the general to the more specific. This is analogous to the leveling and sharpening nature of the design process. This structure is in need of

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|--------------------------|------------------------|-------------------|
| 1. adjacency | 18. facility | 35. position |
| 2. barrier-access | 19. feedback | 36. privacy |
| 3. behavior setting | 20. format | 37. process |
| 4. boundary | 21. gate | 38. property |
| 5. communication channel | 22. generate-terminate | 39. protection |
| 6. comparison | 23. guidance | 40. proximity |
| 7. compliance | 24. implicit | 41. queue |
| 8. conceptual | 25. information | 42. relation |
| 9. content | 26. input-output | 43. replace |
| 10. context | 27. media | 44. seize-release |
| 11. control | 28. mobile-stabile | 45. sequence |
| 12. dependency | 29. motion (speed) | 46. similarity |
| 13. disipation | 30. negative-positive | 47. static |
| 14. dynamic | 31. parts | 48. tool |
| 15. enclosure | 32. people | 49. supervision |
| 16. enter-leave | 33. physical | 50. vehicle |
| 17. explicit | 34. point of contact | |

further refinement, but it will provide a reasonable vehicle for illustrating the manner in which it might be used.

Application

As an illustration, let us consider the design of the architectural students' academic work station—the studio. For the sake of simplicity let us consider two of the many design requirements which might be produced by the analytic phase of the design process:

1. Security from theft. The typical design school layout must permit continuous student access to the student studio areas. This open situation also permits access by strangers whose intention might be theft of the students' work tools.
2. Studio teaching routine. Instructors typically come to the student studios for individual consultation with each student. However, there is often need of group discussion between faculty and students in the studio intermittent with individual consultation.

Consider the structure in Figure 5 and keep in mind that it will be used in top-to-bottom process. Beginning with Requirement 1, we have a group of four student work stations. These are entities which

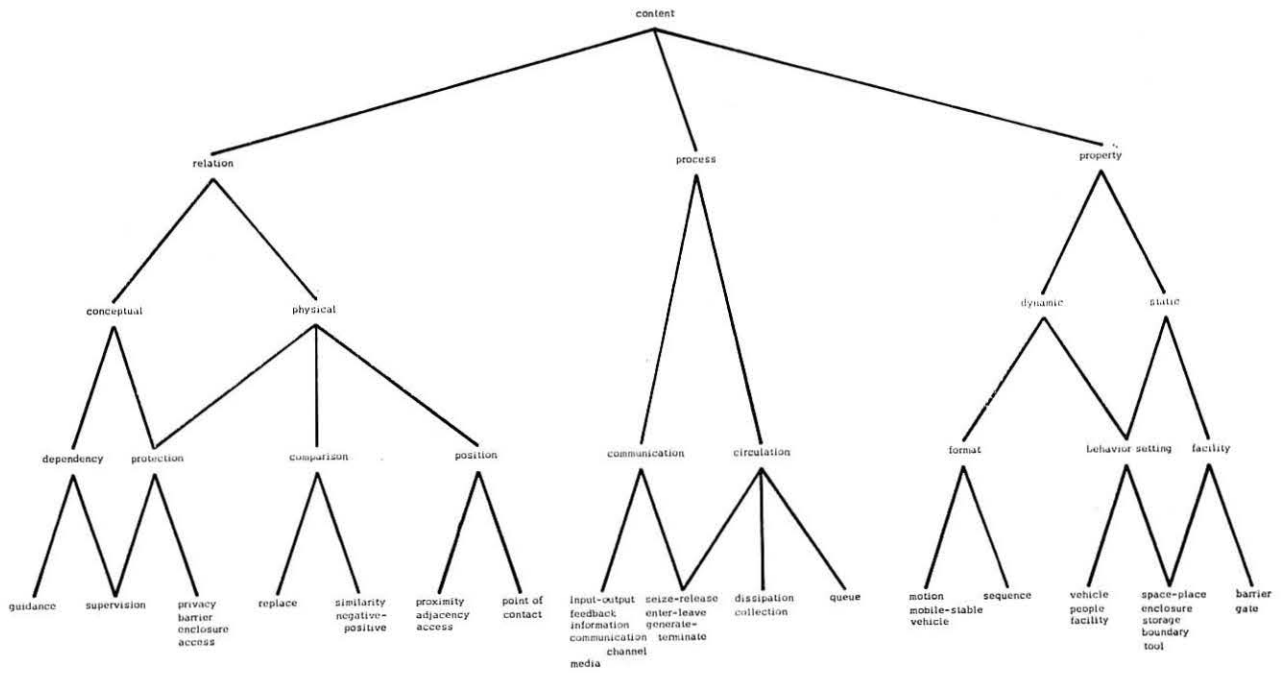


Figure 4. Grammar semi-lattice.

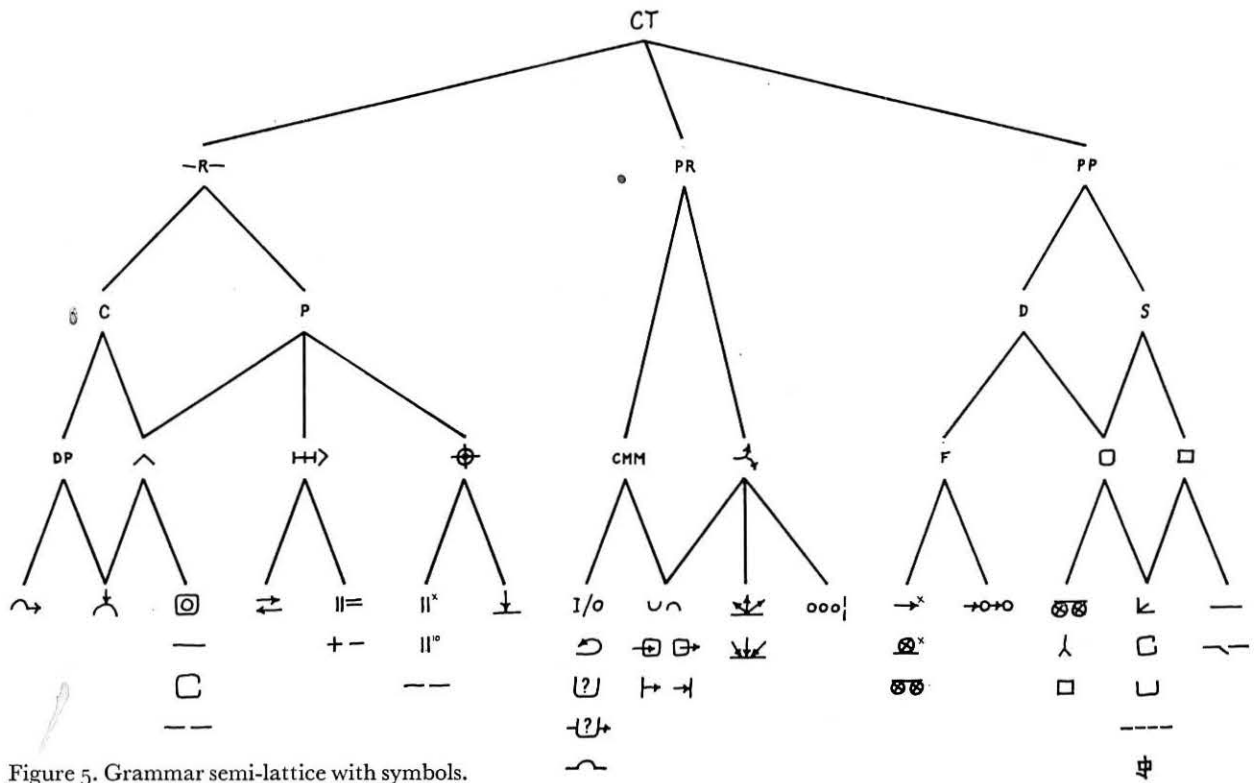
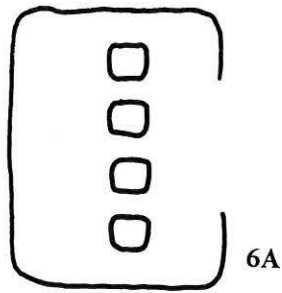
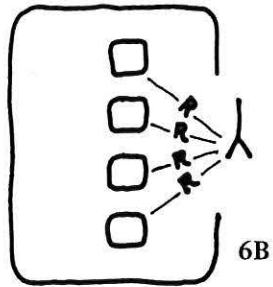


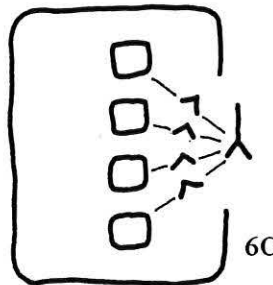
Figure 5. Grammar semi-lattice with symbols.



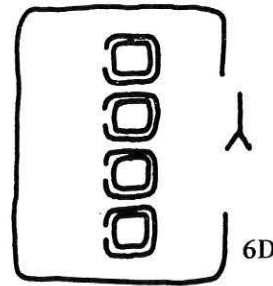
6A



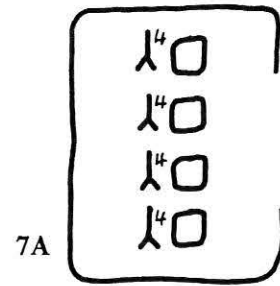
6B



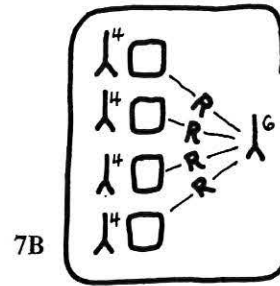
6C



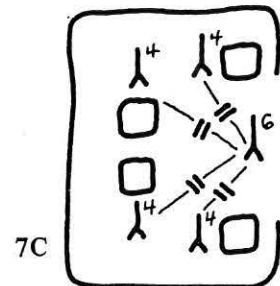
6D



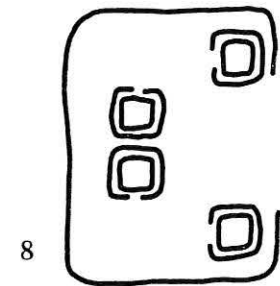
7A



7B



7C



8

are identifiable by their *property* which is both *dynamic* and *static* as a *behavior setting*. Let us place these in a *behavior setting* drawn as an *enclosure* (Figure 6A). In Figure 6B we add another entity whose *property* is *dynamic* as a *person* and is considered to be a thief. This person has a certain *relation* "R" with each *behavior setting*, and the desirable *relation* is *protection* (Figure 6C) which can be accomplished by the addition of an additional enclosure (Figure 6D) about each *behavior setting*.

Continuing with Requirement 2, we have the same four *behavior settings* in their studio *enclosure* (Figure 7A). In Figure 7B a new entity is added as a *person* who is the instructor, and this *person* assumes a *relationship* with each *behavior setting* and the *person* at each of these *behavior settings*. The problem presented is that of group discussion, which might be solved by the instructor being able to assume a position of equal *proximity* to each of the *persons* in the individual *behavior settings*. This might require a rearrangement of the *behavior settings* as in Figure 7C.

The superior figures ("4" and "6") used with the person symbols in the diagrams of Figure 7 refer to the relative roles each of the persons depicted in the diagram play in the behavior setting. The "role" in question is that of relative centrality or "level of penetration" on a scale of 1 to 6 as devised by Barker in his theory of behavior settings.²⁸ Thus, the person with the "6" has a more central role in the behavior setting than those with the "4."

The combination of Figure 6C and 7C is shown in Figure 8. The physical form which will ultimately satisfy the diagram of Figure 8 might be individual work stations arranged in a circular configuration to satisfy the discussion requirement. The theft problem might be

Figure 6 (A) Four student-work stations in a studio. (B) The relationship "R" of the intruder to the work stations. (C) The desirable relationship is protection. (D) Protection is accomplished with an additional symbolic enclosure about each work station.

Figure 7 (A) Four students and work stations. (B) The relationship "R" of the faculty member to the work stations. (C) The desirable relationship is proximity which is accomplished by rearranging the work stations.

Figure 8. Combination of Figure 6D and 7C.

solved by the use of a roll-top structure which could cover the entire work surface in one easy operation.

Conclusion

The example above was, of course, overly simplified; many more design requirements would have come into play in the normal design situation and the diagram would have become quite complex. However, the elements for a basic theory of diagrammatic language are present. The grammatical structure as presented here needs to be tested; the visual elements have to be refined, and numerical notational elements will have to be employed as exponents of the basic visual primitives. The design requirements themselves will, no doubt, have to be written in a special format to make their translation into diagrams as efficient as possible. The next stage of this research effort will be experiments in the use of the language, carried out both in academic and professional environments. The form of the language will undoubtedly change in response to these experiments. Its ultimate efficient use will require, as with any language system, that the language be learned.

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