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Abstract
While numerous algorithms and approaches have been suggested and applied to the problem of space-planning there has not been any systematic comparison or evaluation of these methods. Such an evaluation is important because the spatial configurations produced by such methods vary considerably. In this paper the major space planning techniques, as well as several new approaches and modifications to existing methods, are described, compared and evaluated. The use and consequences of certain options and/or modifications to the basic methods are included and evaluated. The results for each method using an identical problem are given, indicating the comparative speed and optimality of each approach, as well as the final plans generated. The implications of these results and their relationship to the design process are discussed.

Introduction

The past decade has seen a variety of techniques for evaluating and/or automating the space planning process. To a great extent, these allocation techniques have become very familiar to many designers and their utilization has become more widespread. Design literature consistently includes applications, extensions, or computer program descriptions which rely on any number of different space allocation algorithms. The resulting spatial configurations or floor plans are generally presented with discussion reserved only for the end product. Usually, a particular algorithm has been implemented, with certain other related decisions inherent to the chosen approach, and the system or solutions built up from this initial decision. There is little explanation, however, as to why the particular technique has been chosen nor why certain secondary decisions related to the implementation of this approach have been made. The results of any of the many different techniques are not, however, the same. Even the secondary decisions that arise as a consequence of any algorithm yield widely varying solutions. It has, however, rarely been the case where the results or consequences of using each of the different approaches have been carefully evaluated, analyzed or compared.

This paper takes each of the many space allocation techniques available plus several new approaches and compares and evaluates them with respect to one another.

identical example problems are used to clearly demonstrate the differences in results that occur in each case. Comparisons are made of computing time as well as the "scores" of each resulting solution. For every technique used, all possible sub-options are explained and demonstrated to clearly illustrate the consequences of their use. Thus, when the random generating approach is discussed, the implications of a technique which randomly assigns locations to spaces is compared to one that switches locations of two randomly chosen spaces and also to one that only performs the switch if the new random location is within a chosen distance of other elements. Similarly, various approaches and options within the framework of assignment techniques are discussed and compared to one another. Thus, one may see the consequences of various approaches or rules to the spatial location and choice of each incoming element to the plan and/or its dependence toward any or all previously located elements. All approaches are evaluated and compared to one another, and not only to their related generic types.

The purpose of this paper is to both clearly define and illustrate the various techniques available for space planning, to carefully and systematically demonstrate the differences that arise from use of each method, and to evaluate these results. This paper shows that the initial choice of algorithm does have a profound affect upon the resulting design and that the consequences are such as to warrant more serious consideration of certain methods for particular situations. This paper also, in illustrating these techniques presents several new approaches, extensions and modifications of space planning algorithms, heretofore, not presented in the literature. These new techniques are clearly recognizable as logical extension of the choices or decisions that would occur during the manual design process but ignored or avoided previously in the automation of the process.

<u>A Review of Space Planning Techniques</u>

A number of space-planning or allocation methods have, at various times, been developed or presented. For the past ten years, design literature has contained many applications of space-planning techniques as well as extensions of these methods. Comprehensive summaries of these various approaches are given by Mitchell(1) and Eastman(2). Mitchell not only provides an extensive bibliography of space-planning, but also a systematic summary and taxonomy of space-planning techniques which will be referred to in this paper.

With few exceptions, the bulk of space-planning techniques fall into the category of <u>assignment techniques</u>. Essentially, this is an approach which considers the space-planning problem as a combinatorial problem of assigning the various required spatial elements to discrete locations or modules in the available space in such a way as to satisfy a given set of constraints and to optimize some objective function. In general, this objective function relates to the distance between elements and some type of interaction function. This interaction may be expressed as one or more weighted values with either an objective (travel cost, trip volume) or subjective (relative importance, observed hierarchy) basis.

While other approaches to space-planning have begun to emerge recently, many of these are either still in conceptual form and have not been implemented successfully or may not necessarily seek to optimize or improve upon a plan. An example of the former may be found in Grason's proposal(3) for use of graph theory, which seems only successful for small planar graphs. As for the latter situation, the overlay techniques used by Grant[4] or Ward[5] locate elements on the basis of greatest "utility" or "suitability", but this in fact does not seek to improve the relationships between the parts of the plan as much as it seeks to resolve conflicts between the available space and each individual element. The work of Johnson, et al[6] appears closer to resolving the difficulty of other techniques by being best able to internally represent the relationships, the boundary conditions, and geometry of the elements and the space. At present the major difficulty appears to be the large amounts of computer storage and time required for solution and the absence of a "closed-form" problem, thereby preventing the possibility of obtaining a single "best" solution but rather producing several alternative results.

One returns, therefore, to consideration of the large group of assignment techniques. They are important for a number of reasons. First, the bulk of work and literature is centered in this area, mainly because of the relative ease of problem statement and structure. Secondly, the algorithms that can be and have been developed for obtaining solutions by these approaches are such that computation time is generally extremely fast. This has generally led to continued reliance upon and use of these methods and less tendency to seek new or further develop more complex, costlier, and more time-consuming techniques. Thirdly, despite the relatively large amount of activity and writings devoted to these techniques, little if no objective evaluation or assessment has been made of these techniques. Finally, the structure of the assignment model, with its clearly defined objective function provides the means for such an evaluation. This is not to say, however, that other approaches or methods cannot be evaluated. However, many of the other methods, some of which rely only on relationship of element to site of available space, e.g., the overlay techniques, and do not necessarily possess a set of interelemental relationship, could not be "scored" in a similar method and might necessitate a greater reliance upon subjective evaluation.

It should be noted that the general area of assignment technique comprises a wide range of methods. The generic grouping is often assigned to any approach that bears some resemblance to the model description of Brotchie[7] or possesses one or more of the attributes or characteristics of that model. It is necessary therefore to clearly define and classify the different methods within a more detailed framework.

Assignment Techniques

Within the broad classification of assignment techniques, one may first divide all approaches into two distinct classes: 1) constructive or generative procedures and 2) improvement procedures. The constructive procedures begin with an empty field and locate each element of the plan successively in accordance with some given set of rules or algorithm. The improvement procedures take an initial configuration and attempt to modify it so as to produce a better or improved configuration. While this classification provides some means of categorizing the various techniques, a further breakdown is possible by consideration of the algorithms used to improve or generate the plans. These algorithms will be considered in the context of each of the two classes.

A. Constructive or Generative Procedures. As noted above, the constructive procedures are typified by an "ex nihilo" approach to the space-planning problem.

That is, the technique begins with an empty field ("tabula rasa") and locates the elements in accordance with some algorithm. The technique for choosing which element should "enter" the plan and for determining its location provides the means for classification.

1. Random Generation Method. The simplest and most obvious method for generation or construction of floor plans is by random choice of elements and/or locations. The technique employed is a simple one: using a random number generator, successively generate a pair of X- and Y-coordinates for each element on the list of spaces. These coordinates will determine the location of that element on the plan. To prevent an element from being placed in a location already occupied by a previously placed element, a check is made for occupancy. If the space is not vacant, a new set of coordinates are generated. The method may be continued indefinitely with a scoring algorithm used to determine which solutions should be "saved" or printed if one wishes to avoid seeing every solution.

2. Ordered Scores (Assignment Method). This method, the simplest and least sophisticated use of the affinity interaction matrix, builds the plan by choosing the elements in accordance with an ordered list based on total interaction scores. The element with the highest score enters the plan first followed by the next highest scoring element and so forth. The positions of incoming elements are tested for best score within a given radius or distance from previously placed elements. This approach is essentially that of Whitehead and Elders[8] and is essentially that used by Lee and Moore in CORELAP[9], although the latter method does not adhere strictly to the ordered interaction scores in certain cases.

3. Polyomino Assembly (Assignment One). This method is based on the polymino assembly procedure described by Mitchell and Dillon[10]. The choice of elements to enter a plan is made on the basis of interaction with elements already placed and the location on the basis of adjacency to the placed elements. In particular the choice and location of the n + 1th chosen element is based upon interaction with the nth chosen element of the plan. The method may be modified somewhat by the following options:

a. Positioned Elements. Choice of element is based on interaction with all elements already placed on the plan and theelement with highest interaction score individually to the most of the placed elements is chosen for entry.

b. Number of Dependent Elements. Positioning of an element chosen by the previous option may be restricted to only locations around the n elements with which it had the greatest interaction.

c. Interacted Elements. Choice of element to be placed is again chosen on the basis of interaction with positioned elements. The one with the highest score to the most elements is next to enter the plan. Location, however, is only possible next to those elements of the plan with which the incoming element had highest interaction scores.

4. Nuclear Growth (Assignment Two). This method is a new approach to the problem of space-planning. Selection of an incoming element is based upon the scores of the available elements to the cluster of elements previously positioned. That is, if three elements have been placed, the choice of a fourth element is made on the basis of the element having the highest total score to all three of these elements. Position is tested at all points adjacent to these elements. The method differs from the original assignment technique in that this method chooses on the basis of only interaction with positioned elements rather than from a list ordered by total scores. It also differs from the polyomino approach by using total interaction with all positioned elements rather than only with the last element(s). The method may be modified by allowing for:

a. Number of Dependent Elements. Rather than interaction with all previously located elements, choice of element may be restricted to only the last n elements to have entered the plan.

B. Improvement Procedures. As noted earlier, the improvement procedures are those which systematically seek to improve upon the score of the plan constructed in the previous cycle. Elements are re-positioned in an effort to achieve a better score. In general, efforts that fail are disregarded or discarded and computation ceases when no further improvement is possible. Classification is made by the technique used for obtaining improvement.

1. Random Switch. This method takes the initial plan and seeks improvement by randomly switching any two elements of the plan matrix. To avoid switching empty space elements or a non-empty space with an empty space, the restriction is included that only if two non-empty spaces are within a given radius of the empty space will a switch be permitted. This rule also prevents a plan with "detached" spaces and thereby maintains contiguity of plan.

2. Ordered Scores and Alternative Check. This method utilizes the same technique as the first generative technique (Ordered Scores - Assignment). At the end of the plan generation phase, however, a systematic switch of every occupied element with every other occupied element of the space is made in an effort at improvement. A more sophisticated approach to this method uses the option:

a. Alternative Check. This option performs a systematic switch of plan elements seeking improvement at each cycle of the plan generation, i.e., as each new element enters the plan, switches are performed seeking overall plan improvement.

3. Single Switch. This method systematically switches every element of the initial plan with every other element of the plan. Again, to avoid non-contiguity, the rules prescribed for the random switch are invoked. The method also permits K passes through the plan, where a pass is defined as every position switched with every other position (a maximum of n^2 switches for a non-empty space).

4. Computerized Relative Allocation of Facilities Technique (CRAFT). This method has been thoroughly documented[11] and several extensions proposed[12,13]. Basically, elements are interchanged to achieve improvement on the basis of meeting at least one of three criteria: 1) they are the same size, 2) they have a common border, and/or 3) they border on a third element. At each cycle the interchange performed according to these rules is that producing the greatest improvement in score. The procedure ceases when no further improvement is possible.

There are, therefore, eight different assignment space-planning methods which can be modified by invoking the several options. In addition, all the generative methods may include the options:

i. Value Only. This option calculates interaction scores on the basis of relational value X distance, as opposed to:

ii. Value-Area. This option calculates interaction scores on the basis of relational value X distance. This option is useful when elements are of varied size and importance is desired for larger plan elements so that they would enter the plan initially.

Evaluation of the Space-Planning Methods

The various methods and options for space-planning described above were evaluated using as a test problem, a middle school (junior high school). The data for the school including room types, areas, and relationship matrix are shown in Fig. 1. The choice of this building type and its associated program for testing allows for many clearly defined functions and relationships. The number of spaces (twenty-five) permits the possibility of sufficient variation in the final plan configurations and scores which would not be possible with less complex building types or those with a smaller number of spaces.

Using the information given and a set of computer programs developed for each of the methods described above, test runs were performed to assess and evaluate each method. Since scoring was possible on the basis of value X distance in all cases, comparitive scores were obtained. In addition, computer times were obtained for each run to assess speed and cost as well. The scores and computer times for each method and option used are given in Table 1.

With a major objective of any space-planning technique being the achievement of the best possible results without generating excessive costs, it is interesting to note that the variation between the final scores of the various methods is less than 5%. More importantly, the time differential between the worst and best solution is more than forty-fold! This means that for a sacrifice of only 5% in the efficiency of plan, a savings of nearly 20 minutes of computer time (23.2 minutes versus .52 minutes) is achieved. Interestingly enough, a solution only 2% "worse" than the "best" solution can be achieved in 1.02 minutes.

It is surprising to find even with a relatively "small" building, that the solutions generated by the various methods generate so great a variety of solutions. While certain options of each method fail to produce much, if any, change a wide range of

G1G1 9	G1G2 7	G1G3 7	G1G4 7	G1G5 7	G1G6 7	G1G7 7	G1G8 7	G1IA 5	G1HE 5	G1VA 6	G1GS 6	G1UA 5	G1MA 6	G1GY 3	G1SV 3	G1CF 4	G1ST 3	G1KT 3	G1SD 4	G1AD 5	G1LR 8	G1AV 7	G1HC 5	G1GC 5
....	G2G2 9	G2G3 7	G2G4 7	G2G5 7	G2G6 7	G2G7 7	G2G8 7	G2IA 5	G2HE 5	G2VA 6	G2GS 6	G2UA 5	G2MA 6	G2GY 3	G2SV 3	G2CF 4	G2ST 3	G2KT 3	G2SD 4	G2AD 5	G2LR 8	G2AV 7	G2HC 5	G2GC 5
....	....	G3G3 9	G3G4 7	G3G5 7	G3G6 7	G3G7 7	G3G8 7	G3IA 5	G3HE 5	G3VA 6	G3GS 6	G3JA 5	G3MA 6	G3GY 3	G3SV 3	G3CF 4	G3ST 3	G3KT 3	G3SD 4	G3AD 5	G3LR 8	G3AV 7	G3HC 5	G3GC 5
....	....	....	G4G4 9	G4G5 7	G4G6 7	G4G7 7	G4G8 7	G4IA 5	G4HE 5	G4VA 6	G4GS 6	G4JA 5	G4MA 5	G4GY 3	G4SV 3	G4CF 4	G4ST 3	G4KT 3	G4SD 4	G4AD 5	G4LR 8	G4AV 7	G4HC 5	G4GC 5
....	....	....	....	G5G5 9	G5G6 7	G5G7 7	G5G8 7	G5IA 5	G5HE 5	G5VA 6	G5GS 6	G5JA 5	G5MA 5	G5GY 3	G5SV 3	G5CF 4	G5ST 3	G5KT 3	G5SD 4	G5AD 5	G5LR 8	G5AV 7	G5HC 5	G5GC 5
....	....	....	....	....	G6G6 9	G6G7 7	G6G8 7	G6IA 5	G6HE 5	G6VA 6	G6GS 6	G6UA 5	G6MA 6	G6GY 3	G6SV 3	G6CF 4	G6ST 3	G6KT 3	G6SD 4	G6AD 5	G6LR 8	G6AV 7	G6HC 5	G6GC 5
....	....	....	....	....	....	G7G7 9	G7G8 7	G7IA 5	G7HE 5	G7VA 6	G7GS 6	G7UA 5	G7MA 6	G7GY 3	G7SV 3	G7CF 4	G7ST 3	G7KT 3	G7SD 4	G7AD 5	G7LR 8	G7AV 7	G7HC 5	G7GC 5
....	....	....	....	....	....	....	G8G8 9	G8IA 5	G8HE 5	G8VA 6	G8GS 6	G8UA 5	G8MA 5	G8GY 3	G8SV 3	G8CF 4	G8ST 3	G8KT 3	G8SD 4	G8AD 5	G8LR 8	G8AV 7	G8HC 5	G8GC 5
....	....	....	....	....	....	....	....	IAIA 9	IAHE 6	IAVA 4	IAGS 5	IAJA 6	IAMA 4	IAGY 3	IASV 3	IACF 2	IAST 2	IAKT 2	IASD 2	IAAD 4	IALR 2	IAAV 3	IAHC 6	IAGC 2
									HEHE 9	HEVA 4	HEGS 5	HEUA 6	HEMA 4	HEGY 3	HESV 3	HECF 2	HEST 2	HEKT 2	HESD 2	HEAD 4	HELR 3	HEAV 3	HEHC 5	HEGC 3
									....	VAVA 9	VAGS 5	VAUA 6	VAMA 7	VAGY 3	VASV 3	VACF 3	VAST 5	VAKT 3	VASD 3	VAAD 4	VALR 6	VAAV 6	VAHC 3	VAGC 3
									....	....	GSGS 9	GSJA 6	GSMA 5	GSGY 3	GSSV 3	GSCF 3	GSST 3	GSKT 3	GSSD 3	GSAD 4	GSLR 6	GSAV 6	GSHC 3	GSGC 3
									....	....	....	UAUA 9	UAMA 7	UAGY 3	UASV 3	UACF 3	UAST 3	UAKT 3	UASD 5	UAAD 5	UALR 5	UAAV 4	UAHC 4	UAGC 5
									....	....	....	....	MAMA 9	MAGY 2	MASV 2	MACF 3	MAST 6	MAKT 3	MASD 3	MAAD 3	MALR 3	MAAV 3	MAHC 3	MAGC 3
									....	....	....	....	....	GYGY 9	GYSV 8	GYCF 8	GYST 8	GYKT 7	GYSD 6	GYAD 7	GYLR 2	GYAV 2	GYHC 6	GYGC 6
									....	....	....	....	....	....	SVSV 9	SVCF 8	SVST 8	SVKT 7	SVSD 6	SVAD 7	SVLR 2	SVAV 2	SVHC 6	SVGC 6
									....	....	....	....	....	....	....	CFCF 9	CFST 6	CFKT 8	CFSD 8	CFAD 7	CFLR 2	CFAV 3	CFHC 4	CFGC 4
									....	....	....	....	....	....	....	....	STST 9	STKT 7	STSD 5	STAD 6	STLR 4	STAV 5	STHC 3	STGC 3
									....	....	....	....	....	....	....	....	....	KTKT 9	KTSD 8	KTAD 6	KTLR 2	KTAV 2	KTHC 4	KTGC 3
									....	....	....	....	....	....	....	....	....	....	SDSD 9	SDAD 7	SDLR 3	SDAV 3	SDHC 4	SDGC 6
									....	....	....	....	....	....	....	....	....	....	....	ADAD 9	ADLR 6	ADAV 5	ADHC 7	ADGC 8
									....	....	....	....	....	....	....	....	....	....	....	....	LRLR 9	LRAV 8	LRHC 3	LRGC 3
									....	....	....	....	....	....	....	....	....	....	....	....	....	AVAV 9	AVHC 3	AVGC 3
									....	....	....	....	....	....	....	....	....	....	....	....	....	....	HCHC 9	HCGC 8
									....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	GCGC 9

NUMBER	SPACE CODE	AREA	SPACE DISCRIPTION
1	G1	320.0	GEN-LEN-CLUSTER-1
2	G2	320.0	GEN-LEN-CLUSTER-2
3	G3	320.0	GEN-LEN-CLUSTER-3
4	G4	320.0	GEN-LEN-CLUSTER-4
5	G5	320.0	GEN-LEN-CLUSTER-5
6	G6	320.0	GEN-LEN-CLUSTER-6
7	G7	320.0	GEN-LEN-CLUSTER-7
8	G8	320.0	GEN-LEN-CLUSTER-8
9	IA	470.0	INDUSTRIAL-ARTS
10	HE	385.0	HOME-ECOMNICS
11	VA	336.0	VISUAL-ARTS
12	GS	470.0	GENERAL-SCIENCE
13	UA	176.0	UNIFIED-ARTS-COMMON
14	MA	427.5	MUSIC-AREA
15	GY	945.0	GYMNESIUM
16	SV	370.0	GYMNESIUM-SERVICES
17	CF	435.[illegible]	CAFETORIUM
18	ST	95.0	STAGE-PROJECTION
19	KT	60.0	KITCHEN-SERVERY
20	SD	90.0	STAFF-DINING-LOUNGE
21	AD	147.5	ADMINISTRATION
22	LR	792.2	LIBRARY-RESOURCE
23	AV	60.0	AUDIO-VISUAL-SERV
24	HC	45.0	HEALTH-CENTRE
25	GC	80.0	GUIDANCE-COUNSEL

FIGURE I - INPUT DATA FOR SAMPLE TEST PROBLEM

TABLE I

Generative Methods

Method	Options	Score	Time
Ordered Scores			
	No options	57827	.40
	Check alternatives at completion	57779	5.38
	Check alternatives at each cycle	56664	24.20
Polyomino Assembly			
	3 dependent elements/Interacted/Area + Value	58924	.49
	3 dependent elements/Positioned/Area + Value	59218	.52
	3 dependent elements/Interacted/Value	58510	.52
	3 dependent elements/Positioned/Value	58304	.49
	6 dependent elements/Interacted/Area + Value	58578	.57
	6 dependent elements/Positioned/Area + Value	57789	1.02
	6 dependent elements/Interacted/Value	57619	1.02
	6 dependent elements/Positioned/Value	57922	1.04
	9 dependent elements/Interacted/Area + Value	58578	1.02
	9 dependent elements/Positioned/Area + Value	57809	1.09
	9 dependent elements/Interacted/Value	57671	1.05
	9 dependent elements/Positioned/Value	57671	1.05
	12 dependent elements/Interacted/Area + Value	58578	1.03
	12 dependent elements/Positioned/Area + Value	57977	1.13
	12 dependent elements/Interacted/Value	57671	1.08
	12 dependent elements/Positioned/Value	57671	1.14
	15 dependent elements/Interacted/Area + Value	58578	1.07
	15 dependent elements/Positioned/Area + Value	57977	1.23
	15 dependent elements/Interacted/Value	57671	1.11
	15 dependent elements/Positioned/Value	57671	1.20
Nuclear Growth			
	3 dependent elements/Area + Value	57734	1.27
	3 dependent elements/Value only	57771	1.24
	6 dependent elements/Area + Value	58306	1.28
	6 dependent elements/Value	57710	1.23
	9 dependent elements/Area + Value	58426	1.26
	9 dependent elements/Value	57825	1.23
	12 dependent elements/Area + Value	58426	1.25
	12 dependent elements/Value	57896	1.23
	15 dependent elements/Area + Value	58426	1.25
	15 dependent elements/Value	57920	1.22
	all dependent elements/Area + Value	58426	1.26
	all dependent elements/Value	57920	1.23

Improvement Methods

Single Random Switch	Switch	Score
	0	76387
	600	59210
	1200	57528
	1800	57018
	2400	57018
	3000	56919
	3450	56794
	3825	56782
	6000	56782

Time = 37.37

Single Switch	Option	Score	Time
	1 Pass	57899	7.42
	2 Passes	56905	15.34
	3 Passes	56356	23.20
	4 Passes	56356	30.68
	5 Passes	56356	38.49
CRAFT			
	5 x 5 Matrix	58058	23.27
	6 x 6 Matrix	58103	78.78

different configurations are possible. If one carefully inspects the final solutions shown in Fig. 2, it is clear that a wide number of alternatives have been obtained using these different approaches. Methods such as the random generating routine produce a great number of plans, of course, but not many are optimal. The more sophisticated generative techniques do, however, differ in their final product. It can be seen in Fig. 3 that the growth patterns resulting from the different approaches vary sufficiently to produce these variations, but the scores tend to indicate that near optimality has been achieved.

Conclusions

It is probably difficult to denote any one of the many space-planning methods as "best". Nearly all of the methods that have been evaluated here have certain attribute that make them valuable. Even the random generating or random switching routines, both of which are seemingly based on an "unscientific" approach, are valuable to the designer in producing alternatives not foreseeable by a strictly rigorous, rational approach. Clearly, however, if certain methods do little to improve upon a final configuration, but are much more time consuming, there is some doubt as to their values and consideration should be given the more efficient approaches.

On a rational, philosophical basis, one may prefer certain methods of space-planning because the technique more closely approaches the actual design process. The second and third assignment techniques (Polyomino Assembly and Nuclear Growth) are the most sophisticated methods and come closest, in this regard, to a designers process. Despite the fact that scores were not as "good" as that produced by the switching routines, these two techniques have a rational appeal and appear to justify one's faith in the approaches taken by the speed with which they achieve solutions. Clearly, a direct route to solution is more satisfying than a trial-and-error solution.

It should be noted that the improvement techniques, particularly CRAFT, are valuable to any designer by demonstrating alternatives to the initial plan. This is particularly valuable when the initial configuration is one that has been carefully developed rather than arbitrary as in this paper. Unfortunately, however, since the lower bound on the score for a plan is unknown, these methods may perform thousands of needless operations and tests, producing no real improvements. This is the greatest disadvantage to these methods along with the associated lengthy computation times.

For the designer, the implications of these results are three-fold. First, methods exist and can be further refined that can produce good and efficient architectural plans. The adjacency of related elements into well-defined clusters seems to indicate that these methods not only provide efficient plans, but also that these plans are quite similar to those traditional design methods achieved. Secondly, the ability for certain space-planning techniques to quickly generate numerous efficient alternative solutions to a given program and set of criteria provides the possibility for a richer variety of architectural solutions available for investigation than would be possible by manual methods. Finally, and most importantly, the results of this evaluation indicate that many of the different space-planning techniques produce solutions that are all as nearly efficient despite fundamental

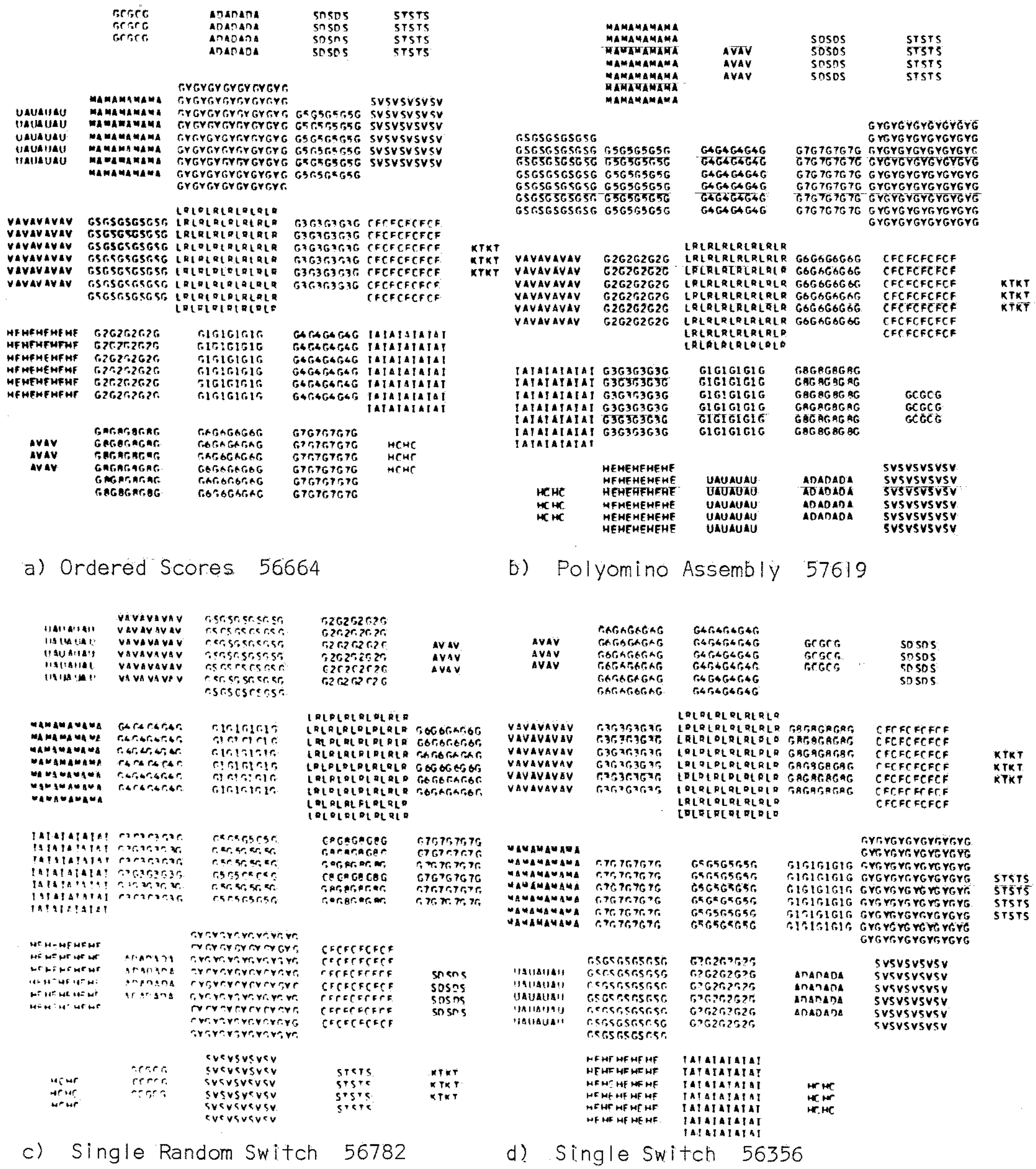

FIGURE 2 - TYPICAL FINAL CONFIGURATIONS

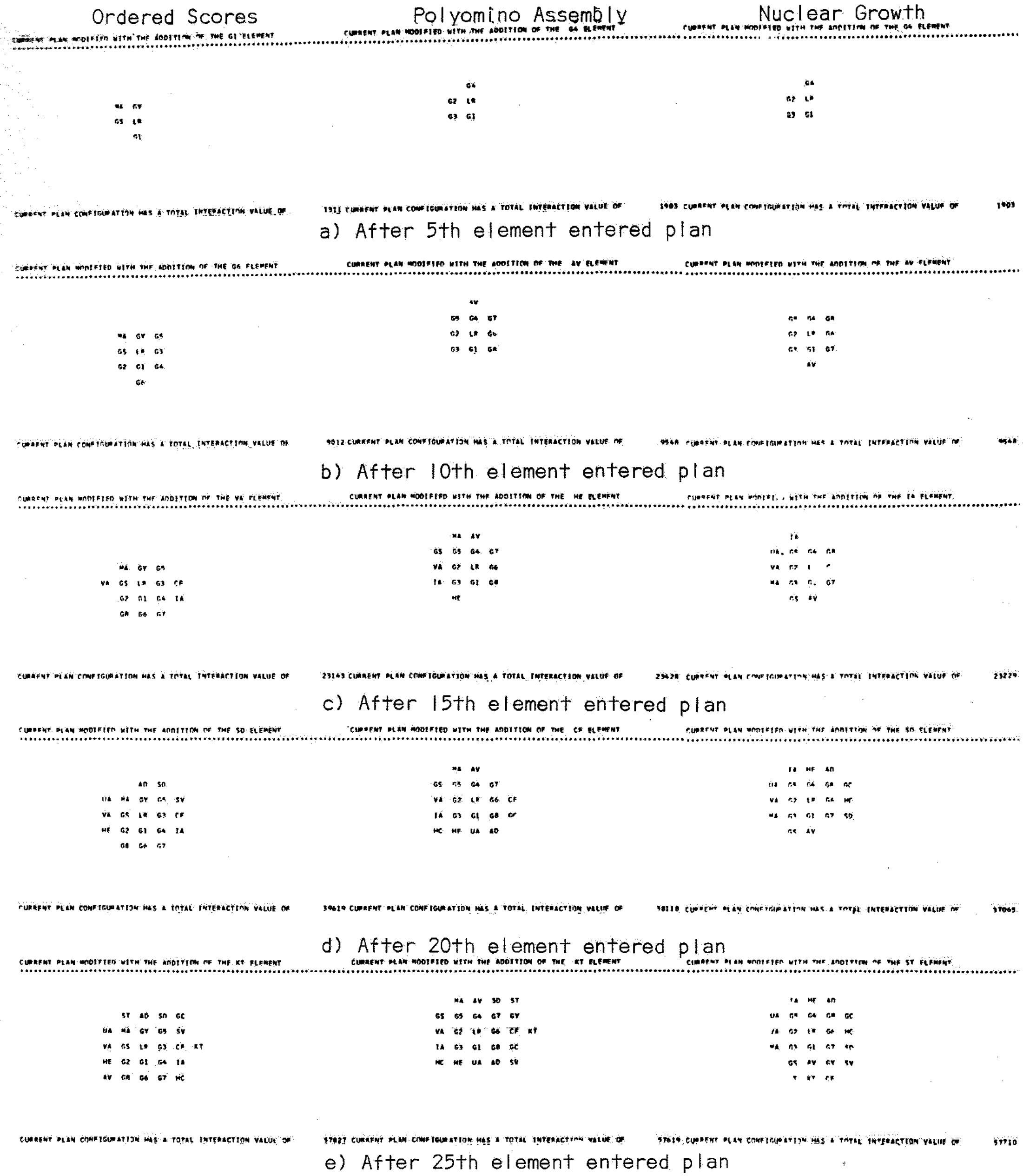

FIGURE 3 - TYPICAL GROWTH PATTERNS

differences in approach. This implies that the designer may choose any method which comes closest to his particular design approach and philosophy and know that his solutions will not suffer in comparison to any other approach.

This final point is most interesting if one looks at the process by which the methods construct the solutions. The elements entering a plan at any stage and their location are often different as a direct result of the problem criteria and the method used. Despite this fact, and independent of type of problem, the final configurations still more than adequately meet the rquirements and standards generally expected of a good architectural solution. The broad implications of this apparent independence of good design solution to individual method may well be the most important result of this evaluation and indicate the continued need for investigation of the entire process of design.

Notes

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