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Abstract Pro-forma

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Paper intended for Session
1 ☐ Design Morphologies
2 ☒ Design Processes, Techniques, Algorithms
3 ☐ Design Objectives
4 ☐ Case Studies

Interactive dimensional layout schemes from adjacency graphs

L.M. Pereira, N. Portas, L.F. Monteiro, F. Pereira

Given a list of imposed and of non-permissible adjacencies between spaces which are to be rectangular, and given a list of intervals expressing the dimensional constraints of each space and of each adjacency, to obtain, by computer, and providing for man/machine interaction, one or more (eventually all) possible layouts on the plane of such a set of spaces. The work relies much on heuristic (although exhaustive) methods to deal with the combinatorial problems involved, and provides for the introduction of additional outside heuristics by means of interaction. The computer programs developed proceed roughly as follows: a) Express the adjacencies by a graph. b) Test graph planarity and obtain one or more (eventually all) possible representations of the graph on the plane. c) Test, for any wanted representation the necessary and sufficient conditions for it to give rise to at least one layout, on the plane, of the rectangular spaces. d). Representations not satisfying the axioms are either rejected, or modified according to heuristic rules. e) Search and find, for each viable representation, every possible layout, dimensions not included yet. f) Assign permissible dimensions to any given layout, which are compatible with the constraints. When a global solution cannot be found, partial solutions can be obtained and interactive facilities allow the reformulation of constraints and/or modification of any one solution in favor of another. Provision is made for diverse interactive modes. g) Finally, any one partial or complete solution can be drawn on a line-printer or on a plotter.

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INTERACTIVE DIMENSIONAL LAYOUT SCHEMES FROM ADJACENCY GRAPHS

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ABSTRACT

Given a list of imposed and of non-permissible adjacencies between spaces which are to be rectangular, and given a list of intervals expressing the dimensional constraints of each space and of each adjacency, to obtain, by computer, and providing for man/machine interaction, one or more (eventually all) possible layouts, on the plane, of such a set of spaces with given types of contour forms. The work relies much on heuristic (although exhaustive) methods to deal with the combinatorial problems involved, and provides for the introduction of additional outside heuristics by means of interaction. The computer programs developed surrender the layouts visually displayed.

1. The problem and the method

In relation to the known literature on the subject* some of the results reported in this paper are not entirely new, although the methods used differ from previous ones.

The problem: Starting out from a pre-established set of adjacency requirements and of non-permissible adjacencies between a set of spatial elements whose shape is assumed to be rectangular, and given a list of intervals expressing the

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* We are refering to the works based on adjacency requirements and graph theory of Levin, Moucka, and especially Grason and Steadman.

dimensional constraints of each space and of each adjacency, as well as the types of forms allowed for the contour, the problem was to obtain, by computer and providing for man/machine interaction, one or more (eventually all) possible layouts on the plane of such a set of spatial elements with all constraints provided for or, optionally, within a given maximum allowance for overlapping.

The solution process: The work relies much on heuristic (although exhaustive) methods to deal with the comfinatorial problems involved, and provides for the introduction of additional outside heuristics by means of flexible interaction facilities.

The computer programs developed proceed roughly as follows:

a) Express the adjacencies by a graph.

b) Test graph planarity and obtain one or more (eventually all) possible representations of the graph on the plane, alterations being made on the graph in necessary.

c) Test, for any desired representation thus obtained, the axioms of the theory, i.e. the necessary and sufficient conditions for it to give rise to at least one layout, on the plane, of the rectangular spatial elements, with considering yet at this stage neither the desired types of contour form nor the dimensional constraints, since these are theory independent and must be introduced by additional axioms derived from their specification. They are accounted for at subsequent stages of the analysis, further down.

d) Reject representations (also called realizations) not satisfying the axioms of the theory or modify them according to heuristic rules with the purpose of rendering them fit for production of at least one layout.

e) Search and find, for each viable representation detected, every possible layout of the rectangular spatial elements which respect the adjacency constraints as well as the admissible types of contour forms. Dimensions are not included yet at this stage, inasmuch the several layouts possibly obtained are defined only topologically.

f) Assign permissible dimensions to any given layout, which are compatible with the constraints, if a solution exists. Specified amounts of dimensional overlapping can be considered if so desired. When a global solution cannot be found, partial solutions can be obtained and interactive facilities allow the reformulation of constraints and/or modification of any one solution in favor of another, when such a modification is permissible. Provision is made for diverse interactive modes, and for filing intermediate or final solutions.

g) Finnaly, elected solutions are visually displayed.

Further Research: Research now in progress aims at relaxing the rectangular requisite for the spatial elements, and coping with the problem of underspecified adjacency requirements. Interaction capabilities will remain a prevalent underlying aim, inasmuch the authors are convinced that such is one of the most promising lines of investigation in what regards "explicit" design philosophies. Such convictions will be touched upon in our next considerations.

2. Conclusions ... Criticism on the state of the art and future research.

The results extracted through the methods developed may be regarded only as topological arrangements of a set of rectangular spaces, but although dimensional constraints have been introduced, and T - shaped and L - shaped spaces for example can be envisaged by appropriate combinations of rectangles, one has conscience that serious difficulties still persist at the level of problem formulation and in the design of the design steps required to tackle it.

In a man/machine interaction process such as the one we developed, which is a still quite rigid, a seemingly better "architectural" output would probably result in a loss of information. Its cost would be premature blind and restringent elimination of hypotheses(*) that could reveal themselves as promising, once some formal adjustments or even compromises be made by the designer's own current heuristic processes, thus saving them. Such processes are characteristically difficult to

(*) In our opinion, in discussing systematic design methods, namely those envolving generating algorithms, it becomes desirable to elucidate what is lost inside the black box, so that it can be retrieved and our knowledge about the box clarified.

program as a means to evaluate and decide, and hinge on further knowledge about problem solving and problem finding, nottonly in general but in design situations in particular.

Our present methods, nevertheless, have tried to explore faster search processes by utilizing some heuristic criteria. The obtention of all layouts from a given representation of a graph, the search for a permissible dimensional solution to a topologically specified layout, and the syntax used for evaluating the contour form, stand as typical examples where the use of heuristic guidelines is helpful, if not indispensable.

An important point can be made for the generative algorithms used, in that not only "positive" information is given in the form of feasible layouts, but "negative" information is also provided in the form of conflitous layouts output, localizing thus ythe reasons for incompatibilities. Appropriate reformulation of such layouts can be the stimulus for the rethinking of design requirements by the user. Interaction, on the other hand, makes such process less burdensome. We hope, furthermore, that the experience gathered in this area will prove to be of use in other developments, wherever situations of insufficiency or conflict among design requirements might arise.

3. The major debility of present systematic methods resides in the reductionism they imply on the formulation of a problem, be that on the semiatic level or inclusively from a functionalist point of view.

In the methods we have developed, such a reduction manifests itself in that the type of results comes to be determined only by those semantic or pratical contents that can be conveyed in terms of a priori adjacencies on a plane. In a prior work(*), the strictly spatial concepts of "compatibility" and "conection" between elementary units of activity/space were explored, showing how the designer can express culturally significant contents by means of adjacencies. Naturally, an input consisting of adjacencies implies a deep prior examination of the problem's requisites, especialy in the sense that an all or nothing contiguity between each pair of spatial elements is, of course, already a form a architectural output, which carries implicitly chosen (and unchosen) decisions about the pattern of spatial relations

(*) PORTAS, N. (1965). Evalution des normes du logement. Cahiers du C.S.T.B. nº. 572, Paris.

hips. However, the formal conception of an architectural organism can be distorted by giving a priori privilege to the obtention of a set of optimum relationships among its internal component spaces. (The same could be said of former methods based on traffic matrices).

The problem should be solved instead by conciliating a relatively satisfactory subset of geometric adjacency relationships. . With other principles of form corresponding to aditional in put solicitations,

Let us for the moment assume that in architectural design there is a dialectic" "composition" of two main processes, sometimes overlapping sometimes sequential along the actual design process. The first one, deductive, permits, in our case, to generate candidate solutions and test them against an explicity defined grammar of spatial well-formedness according to rules expressing the articulation of elementary or local requisites. The second one, inductive, tries to enact generic principles of form underlying architectural types, which can be in put as hypothetical structures through appropriate manipulation, in the program, of global properties, to be considered by the program, must also be amenable to some grammar, as is the case with the types of contour form permitted, and which we can already consider.

In the case of development schemes however be they linear, focal, grid, cluster, etc.), they have to be checked against actual information about the their coded meanings at the semiotic level.

The inductive steps, i.e. the building of grammars regulating global properties, are particulary important for ensuring the correct deployment of the layouts being generated by deductive schemes alone, thus embodying them in formal structures which could not arise simply from the logic of elementary interrelations.

Two types of difficulties in design methodology can be identified which results from the multiplicity of inputs and the feedback processes of "goals" and "form" in architectural organisms. The first deals with the gap in the actual levels of knowledge (concepts and codification) between the requirements, considered as inputs, and the logic of general patterns of from that may embody them. Such a difference does not allow the same level of explicitation to be used when defining both requirements and spatial typologies. That difficulty explains the reduction inherent in our methods, inasmuch they lead to expressing the complexity of spatial re lationships by means of simple adjacency specifications. We need a far more develo ped language to talk architectural language itself, as a condition for the progress of design methodologies.

The second type of difficulty results from the impossibility of establishing a priori, i.e. in a standard architectural program, a hierarchical order representing the relative weights among requirements very diverse in nature. For one thing, the hierarchical relation of importance between successive input requirements cannot be transposed into a pre-established sequential ordering of design process decisions; for another, the "problem formulation" is neither independent nor necessarily previous to the guessing of hypotheses concerning the structure of the solution, particularly on the level of the unit "significate/signifier", by which the vehicle form is itself a requirement statement making up the problem formulation.

Thus, in the work being carried out our aim has been to make interact not only the designer and the program, but also the requirement inputs (adjacencies, dimensions, and others), with the typological inputs, i.e. pre-established principles of form embodying complex and general systems of requisites (metadesign). Such an interaction, however, does not determine a priori the precedence of one type of input over another, but explores the possibilities of conciliation as well as their price, their price, thus permitting a step by step evaluation, and a re-orientation of the initial problem formulation itself.

4. Last but not least, we present three output specimens for the same graph. Sometimes there exists an essential incompatibility between the topologically defined candidate solutions and the dimensional requisites partaking it. The result is some degree of overlapping. In this case the overlapping bounds specified by the user allowed the "solution" to be output. Unfortunately, the space is scarce to exhibiting a representative spectrum of layouts for a given graph. Such task is usually left to our computer.

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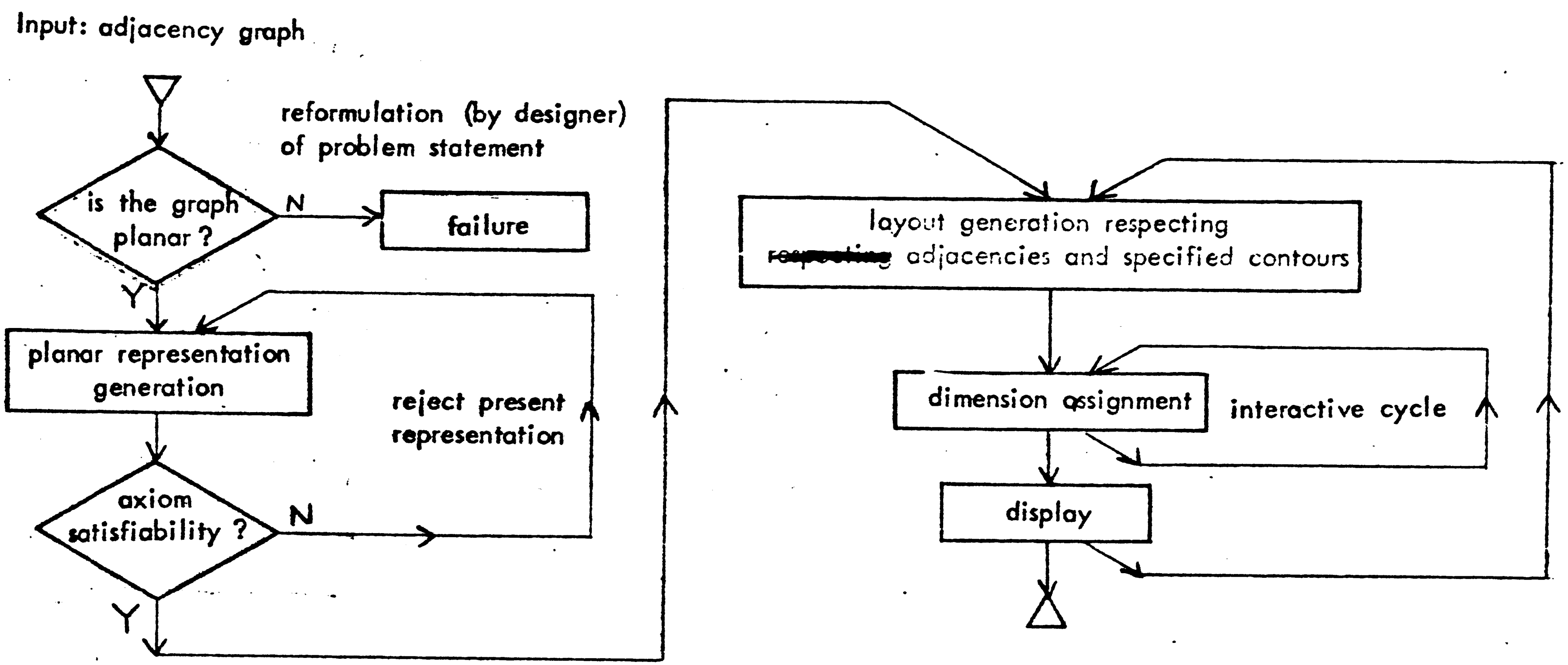
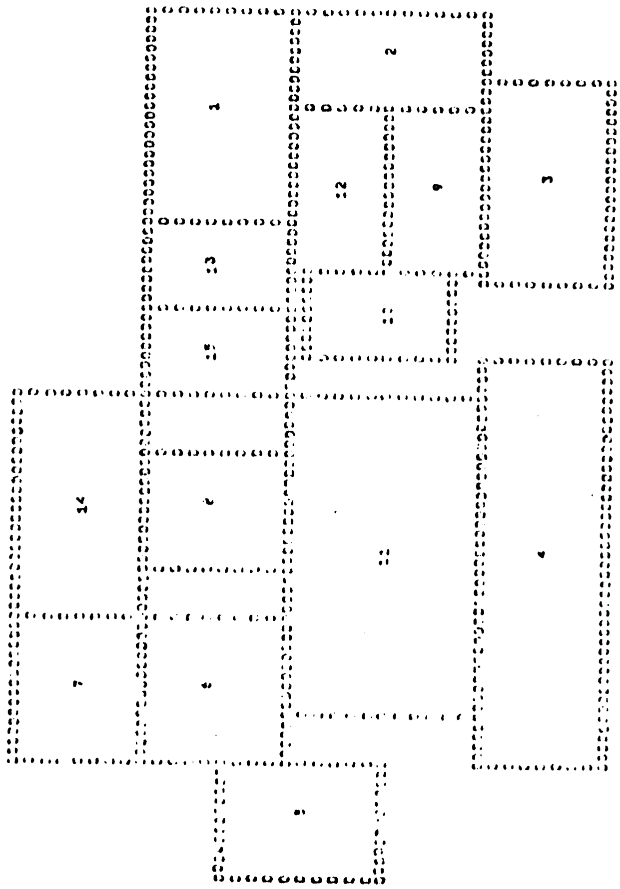
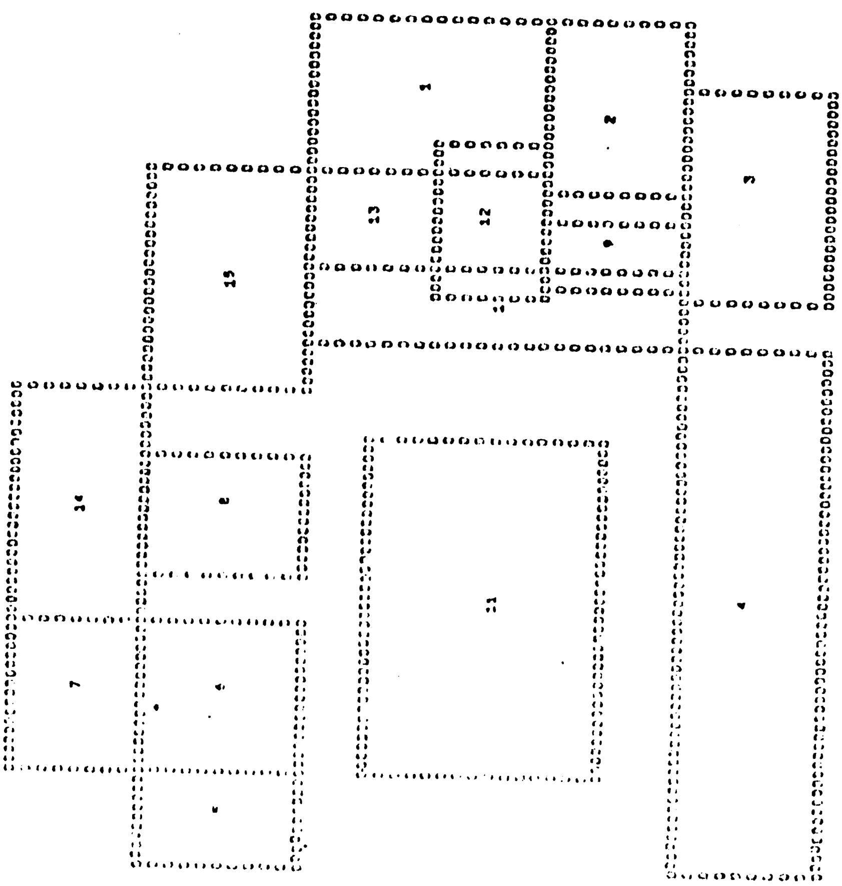
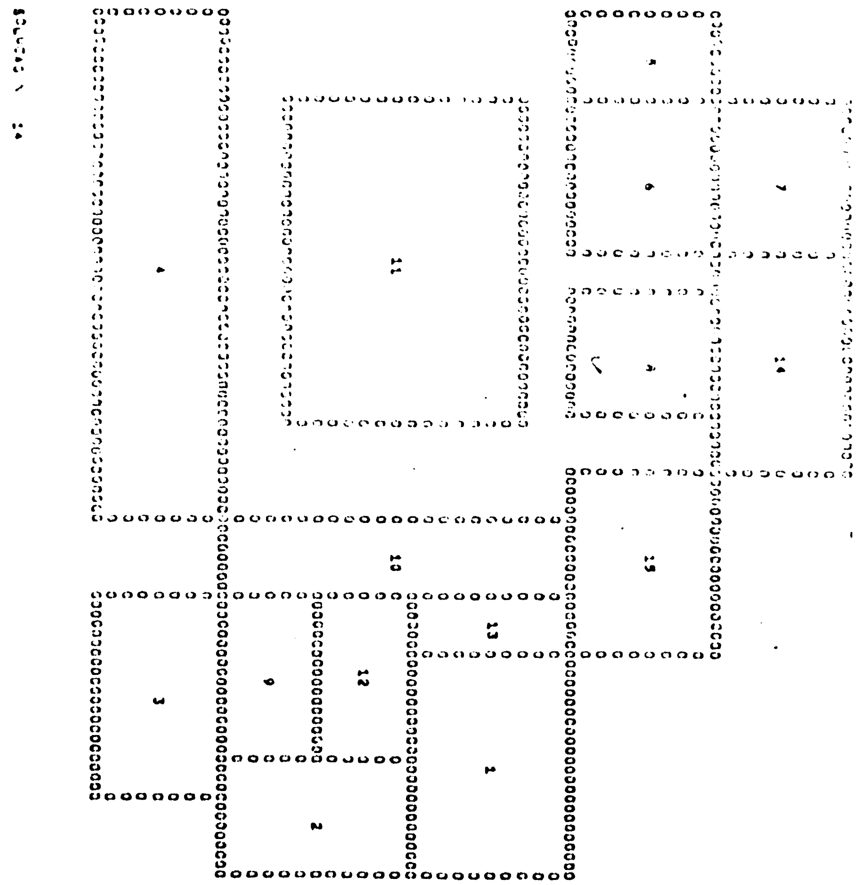
LAYOUT SCHEME GENERATION PROCEDURE









Time taken, referred to the paragraphs of section 1:

b) 20 seconds

c) negligible

e) 7 seconds for solution

f) 6 seconds for solution

g) 8 seconds (lineprinter), in an ELLIOT - 4100 with 6 microseconds store.

Eighty solutions were obtained for this graph.