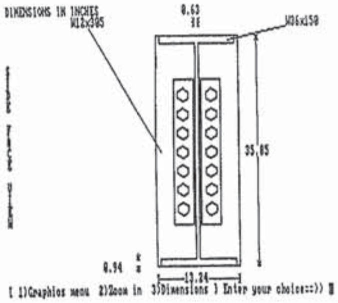

Fig. 7

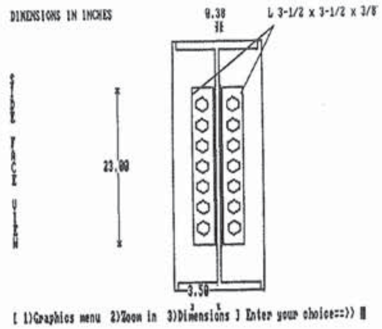

Fig. 8

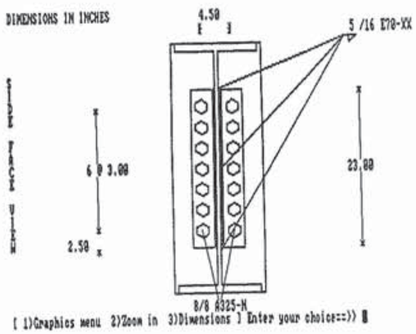

Fig. 9

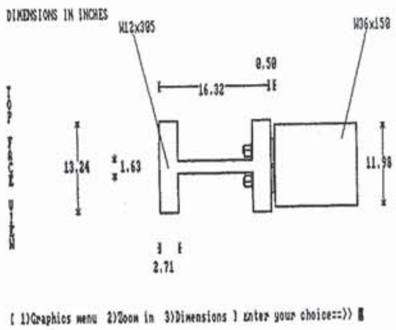

Fig. 10

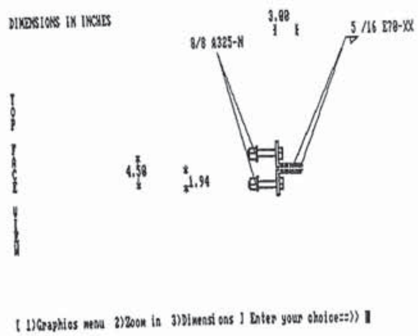

Fig. 11

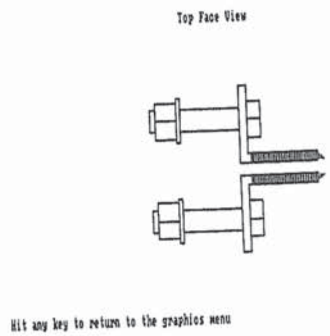

Fig. 12

A COMPUTER-AIDED ROOM ALLOCATION MODEL WITH CONCEPTS OF FRAMABLENESS AND FLEXIBLE CONDITIONS

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KEYWORDS

Computer-aided Design, Room Allocation, Framableness, Flexible Condition, Fuzzy Set Theory.

ABSTRACT

On the Computer-aided room allocation system, it is required to treat the particularities of architectural design. Major particularities we must consider in CAD of architecture are 1) one of building system and 2) one of design process.
On the building system, we found that it was difficult to make a reasonable plan from an architectural viewpoint through simulation studies by the conventional room-allocation CAD which had not the concept of framableness. Therefore, we make a criterion of framableness which is defined by the geometrical relationship of beams, columns and walls. In the algorithm, we apply the multi-stage searching method developed in the field of artificial problem solving.
On the design process, a slight violation for given initial condition sometimes is allowed because the initial condition is not so rigid and the condition itself is reevaluated and modified by architect in the design process. From this viewpoint, we establish the concept of "flexible condition" and formulated by use of Fuzzy set theory. For the design under the flexible condition, we built a room allocation CAD system in which we apply the artificial learning system in order to fit the response of system to judgment of architect.

UN COMPUTER-AIDE PIECE ARRANGEMENT MODELE
AVEC CONCEPTS DE BATIMENT CHARPETE ET CONDITIONS FLEXIBLES

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Mots-clés

Computer Aidé Dessein, Pièce Arrangement, Bâtiment Charpente, Conditions Flexibles, Fuzzy ensemble théorie.

Sommaire

Sur le Computer-aidé pièce arrangement système, c'est requéri de traiter les particularities de dessein architectural. Particularities majeures que il faut considérer dans CAD en architecture sont 1) un du bâtiment système, et 2) un du dessein procédé.
Sur le bâtiment système, nous avons trouvé que c'est diffcile de faire le plan raisonnable au point de vue architectural par simulations du pièce arrangement CAD ordinaire sans la concept de charpente système. Donc, nous faisons le critérium du charpente système raisonnable qu'est défini par la connexité géométrique de poutres, colonnes, et murs dans bâtiment plan.
A l'algolithme, nous appliquons la méthode multi-degré cherchant, qu'est développé dans le champ de la intelligence artificiale.
Sur le dessein procédé architectural, quelquefois une violation légère de la condition donnée à le premier etage est permis parce que la condition initialé donnée n'est pas si rigide et la condition est vérifiée et changée par le architecte dans le dessein procédé. A ce point de vue, nous establissons le concept de "conditions flexibles" usant de Fuzzy ensemble théorie.
Nous bâtissons un pièce arrangement CAD système avec la condition flexible, dans lequel nous appliquons le système de intelligence artificielle dans le but de adapter la response de système au judgement de architecte.

1. THE BACKGROUND AND AIM OF THE STUDY

The utilization of recent sophisticated computer technology in architectural design has enormous potentials to reduce the effort required for a simple repetitive operation during the design process and to enable the designer to put more time in thinking creative thoughts. In order to bring these potentials to realization, further investigations will become much more necessary of what techniques should be established, seen from the architectural design side as well as from the computer technology side, so that computers will become truly worthy of utilization.

In the present study, the floor-plan designing (room allocation), which is a fundamental process in architectural design, is taken up, the computer systems which aid it are considered from the above-mentioned viewpoint, and improvement in these systems are proposed.

2. CAD PROBLEMS SEEN FROM THE DESIGNER'S SIDE, AND ITS IMPROVEMENTS

With respect to CAD systems for room allocation, a model for room layout by a method of successive approximation has already been proposed by Okazaki,et al.(Ref.1) In this study a program for the successive approximation-type layout model proposed by them was formulated and investigated. This model employs the degree of adjacency as an index of the positional relationship between rooms so that the higher the degree of adjacency between two rooms is, the closer they may be allocated to each other. When the room names, room shapes, the degrees of adjacency between rooms and the initial room allocation are put in by the designer, the computer minimizes the total sum (hereinafter called "the adjacency degree evaluating function") of the products of both the degrees of adjacency between rooms and the distances between the centroids of rooms, and then outputs a room-allocation plan as shown in Fig.1.

The authors had designers put in designing conditions according to this program, and had them point out improper or objectionable points in the resulting plans ; thus, several plans were sorted out as the ones which did not give an impression of an "architectural plan". Obviously all of these plans thus sorted out had the following architecturally improper points, as shown on the plan of Fig.1: a) Meaningless empty spaces appeared, b) It was not likely that if beams and girders were put as indicated on the plan, a satisfactory frame could be set up which could firmly support the roof truss. This result may be taken to indicate that it would be better to think that designers unconsciously take framableness into consideration even at the initial stage of their designing.

Furthermore, from a result that the authors had the designers improve these "architecturally improper plans", it became apparent that the designers would carry out the following two types of plan changes:
1) Changing the positions of rooms in order to improve framableness,
2) Making the plan more excellent by modifying the shapes of rooms.
Item 1) suggests that an algorithm for changing the positions of rooms to improve framableness is necessary. Item 2) is full of very important suggestions; namely, after examining the allocation balance of whole rooms, designers change even the shapes of rooms which have initially been specified

by themselves, as required, to create more superior floor plans. Ordinary, problem-solving techniques search for optimal solutions within the range of given conditions, while, with grasping collectively the substantial meaning of problem, architects change even the conditions which have been given by themselves, to search for more excellent floor plans.

In the present study, the incorporation of evaluating functions for framableness is proposed with respect to Item 1). As for to Item 2), the concept of the flexible conditions which are flexibly or pliably understandable under synthetic judgment is proposed instead of the concept of fixed conditions used in usual, problem-solving procedures, and the formulation of such flexible-condition concept is still further proposed.

3. EVALUATION OF FRAMABLENESS

3.1. Evaluation Items and Evaluating Function for Framableness

The vague ideas occurring to the designer's mind at the time of designing a floor plan may be put in order as follows:

(1) For the purpose of improving economy while ensuring safety, two rooms or more are made to share (a)walls,(b)beams,and (c)columns with one another.

(2) For the purpose of improving safety while ensuring economy; (d) Continuity is imparted to beams; (e) The length of the beam is made uniform; (f) The shape of the floor plan is made to be full of unity; (g) The placement of walls is made well balanced.

Subitems (f) and (g) are difficult to investigate both before a final room allocation is determined and before a more detailed structural designing is carried out. Therefore decisions were made that subitems (a) through (e) which were thought to be cognized by designers from the initial stage of their designing would be taken up as evaluation items for framableness in a room allocation CAD system and that an algorithm for such subitems would be developed.

Let the total number of rooms be k and define the each variable as shown as Fig.2, then the evaluating functions on the above evaluation items are represented by E1 through E4 shown in Table I, and the evaluating function for the whole framableness is represented by the weighted sum E of these evaluating functions E1 through E4. The weighted sum of this evaluating function E for the whole framableness and the adjacency evaluating function Q is designated as the overall evaluating function F.

In each step of the successive approximation procedure, (1) the values of overall evaluating function F are calculated for all possible plans which are changed from temporal plan by moving a room for four directions,that is, the number of changing alternatives is four times of the number of rooms, (2) a changing alternative is selected as the greatest decrease of F. This procedure is repeated until the value of function F converges.

3.2. Room-Allocation Method by the Use of a Multi-stage Searching

From the results of having executed a program of the above procedure, it was found that there were some cases where the minimization of the overall evaluating function could not necessarily be achieved by the use of a

conventional algorithm for a successive approximation-type model in which an evaluating function is successively minimized step by step, since the result of calculation made in one stage or more ahead cannot be foreseen by use of the usual algorithms when there may be cases where the evaluating function can be further decreased.

In order to solve the above-mentioned problem, the concept of multi-stage searching is introduced. However, the number of the alternative branches in the decision tree, on which we must calculate the overall evaluating function corresponding to each branch, becomes prodigious as shown in Fig.3. Since the number of alternative branches increases by geometric progression and so long as a multi-stage searching is employed, it is necessary to establish beforehand a method for substantially reducing such enormous amount of calculation. Thus, it was decided to incorporate into the algorithm a "pruning method" for a multi-stage searching in which useless alternative branches are eliminated in advance, namely, the number of alternative branches is reduced beforehand, by judgment by the use of simple pruning function, followed by calculations of the overall evaluating function.

Shown in Fig.4 are the example of the results of execution of the program.

4. CONCEPT OF FLEXIBLE CONDITIONS AND ITS APPLICATION

4.1. Concept of Flexible Conditions and its Formulation

In order to analyze the concept of conditions in architectural design, let us take up as an example a condition that "the area is X0 m^2." When the designer with the cognizance of this condition has made out both a draft A of a floor plan on which the larger than X0 m^2 by only 0.01 m^2,but which is very excellent, and a draft B on which the area is X0 m^2 in accordance with the condition, but which is not very attractive, he may sometimes adopt the draft A in disregard of an excess of 0.01 m^2 over X0 m^2. In this case, the foregoing condition had to be a looser one that "the area is approximately X0 m^2." Like this, many of conditions laid down by the designer prior to his designing are the ones which are:

(1) loose at the beginning of the designing, and

(2) permitted to be modified from the synthetic point of view as the design work progresses.

A condition that has the above two properties is designated as a "flexible condition."

The line of thinking in the theory of fuzzy set is utilized to describe the concept of the loose condition (1). A condition that "the area is approximately X0 m^2" can be expressed in terms of a membership function as shown in Fig.5. A parameter k in this function indicates the degree of rigor or severity of condition : that is, the condition tends to become loose as k approaches zero, it tends to become rigorous or severe as k tends to plus infinity, and it agrees with ordinary condition in the limit when k approaches plus infinity.

Considering the modifiable condition (2), the concept of flexible condition can be formulated by setting up a new synthetical evaluating function by weightedly summing up a given overall evaluating function and the above menbership functions.

4.2. Application of the Concept of Flexible Condition to Room Allocation

An attempt is made to apply the concept of flexible conditions to the successive-type room allocation procedure previously described, for the purpose of confirming the effectiveness of such concept.

A menbership function describing the condition of the shape of each room is first set up on the assumption that this condition is flexible. In this case, quantities describing the room shape include:(1) the area; and (2) the ratio of square root of the area to the perimeter.

If the dimensions of the room as measured along the X and Y directions as initial conditions are taken to be X0 and Y0, respectively, then a concrete menbership function is as follows:

$$T(X,Y|X0,Y0)=\exp(-k((\ln\frac{XY}{X0Y0})^2+(\ln\frac{XY(X0+Y0)}{(X+Y)X0Y0})^2))$$

The weighted sum of the overall evaluating function F and the membership functions Ti for the shapes of rooms is defined as the final synthetical evaluating function G.

Furthermore, since the parameter k showing the degree of severity of conditions varies with the designer, an algorithm similar to that of kind of "learning system with a teacher" was prescribed which could be modified when the value for the parameter k did not agree with that obtained by his judgment, so that the parameter k could reflect his personality.

Illustrated in Fig.6 is an example of floor plans of a dwelling house made up in this way.

5.CONCLUSION

In this study, in order to eliminate the obviously inadequate from architectural viewpoint floor plans contained in the output plans obtained by conventional room allocation CAD systems of usual successive approximation-types, attempts were made to improve the usual systems by adding evaluation for a fundamental framableness to floor-plan planning, further investigating the concept of conditions in architectural design, and newly formulating and applying the concept of flexible conditions.

REFERENCES

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Table I. Evaluating function for framableness

evaluation items	evaluating functions*
a, b	$E1=\sum_{i=1}^{k}\sum_{j=1, j\neq i}^{k}[-Lij/(R0+Rij)]$
c	$E2 = Nx+Ny$
d	$E3 = \sum_{i=1}^{k}\sum_{j=1, j\neq i}^{k}[\sum_{t=1}^{2}(-\frac{DxiDxj}{R0+\lvert ypi(t)-ypj(t)\rvert}-\frac{DyiDyj}{R0+\lvert xpi(t)-xpj(t)\rvert})]$
e	E4 = [standard deviation of Sx(n)] (n=1,2,...Nx-1) +[standard deviation of Sy(m)] (m=1,2,...Ny-1)
evaluating function for the whole framableness	$E=\sum_{i=1}^{4} WiEi$
overall evaluating function	$F= wQ+(1-w)E$

* variables used in the functions are as follows. (also shown in Fig.1)

Lij (Rij):the length (distance) of sharing walls or beams
Nx (Ny):the number of lattices in east-west (north-south) direction
Dxi (Dyi):the east-west (north-south) width of room i
xpi(1)(xpi(2)):x coordinates of the western (east) wall of room i
ypi(1)(ypi(2)):y coordinates of the southern (north) wall of room i
Sx(n) (Sy(m)):the intervals of lattices in east-west (north-south) direction
R0 :a coefficient to prevent a dominator from becoming zero

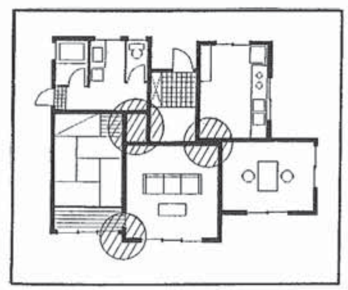

Fig.1 Output plan by a model with a method of ordinary successive approximation

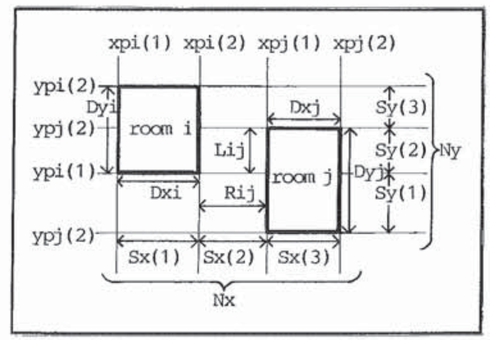

Fig.2 Definitions of quantities

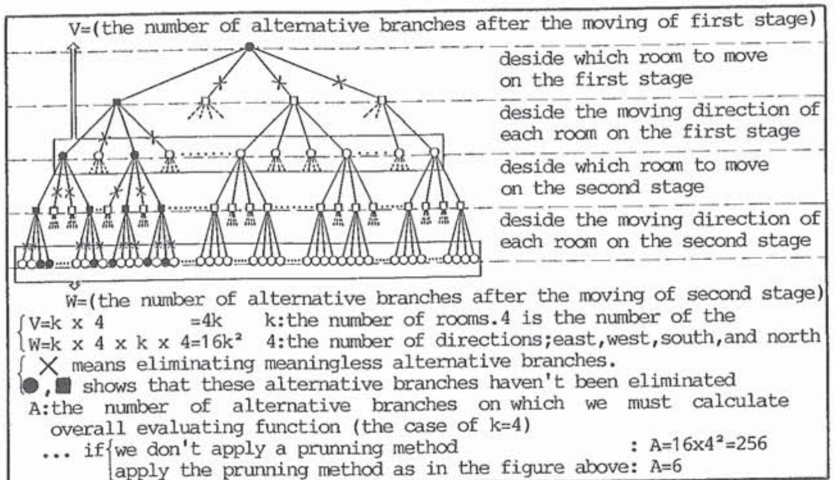

Fig.3 Explanation for a multi-stage searching and a prunning method (the case of four rooms)

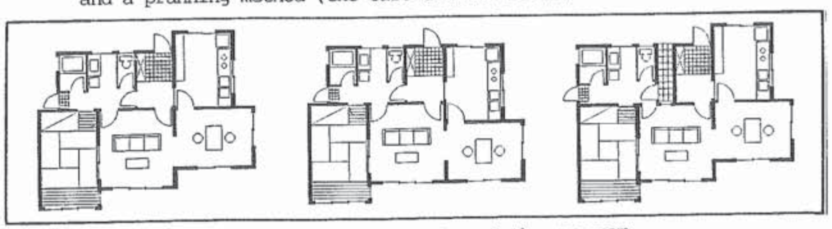

Fig.4 Examples of the results of execution of the program

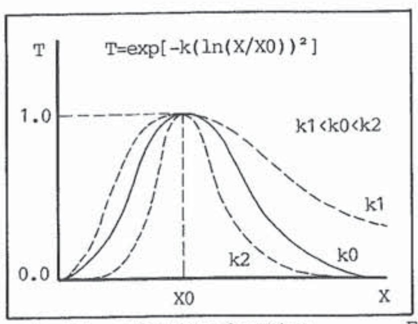

Fig.5 A membership function of flexible condition

Fig.6 Output plan by a model considering with a concept of flexible condition

Computer-aided design and its implications for the management of construction projects

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KEYWORDS

Construction management, Computer-aided design, Data bases, Integration.

ABSTRACT

Many of today's computer-aided design (CAD) systems appear to be concerned with little more than the rapid production of drawings. This has given rise to a research project which is intended, amongst other things, to integrate time, cost and operational data into the working arrangements of a CAD system. By concentrating upon the needs of construction managers, it has been possible to examine the ways in which present generation CAD systems might be developed further to provide information for the management of construction projects. An overall structure for a CAD system, which is capable of providing this information, is proposed. It is based upon the structuring of an information-base which is manipulated by a relational data base management system (RDBMS) incorporating fourth generation programming language capabilities. In this way, a working system is possible which satisfies, not only the needs of the designer, but also those of the other members of the design/construction team. This should lead to greater certainty in design by providing more immediate feedback on time and cost.