8 Interactive Optimization
A Practical CAAD Model

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In recent years, the CAAD technique become more and more popular in most of architectural design institutions in China. Then, like in many other countries, CAAD in China is mainly used for making working drawings and perspectives, a drawing tool not a design tool, and the traditional architectural design process still remain unchanged. The decision making and layout approaching of the designs are based on the skills and experiences of architects, lacking of effective means for architects making design analysis and evaluation during designing.

CAAD, a new technique, creates a new way to make architectural design more efficiently and scientifically. It will totally change the traditional architectural design routines.

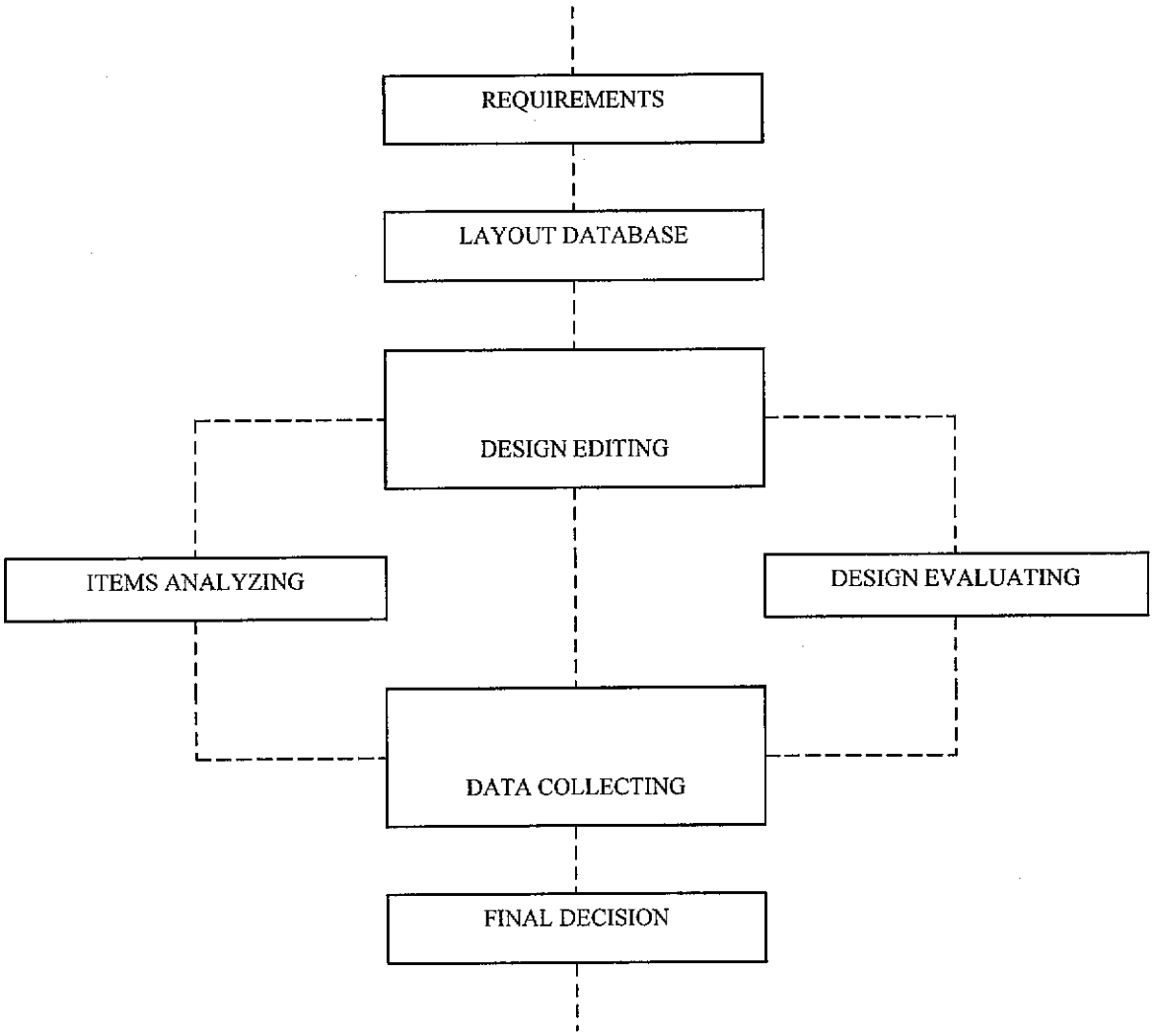
CAAD technique applications can be classified into three basic levels according with its features and the aspects involved. In the first level CAAD is only the meaning of computer aided architectural drawing of drafting. In the second level more design analysis and evaluations are involved and CAAD graphic technique can be used as a tool for architect's thinking. In the third level, new methodology and design theories are more involved such as new 3D design method, systematic design, artificial intelligence and expert system etc. We are standing on the first level and going to step on the second level.

Architect, the human brain, has its characteristic creativeness and conscious activity and computer, the electronic brain, is a powerful and intelligent machine. It can process both numerical and graphic information in high speed with high correctness. It has huge amount of memory to store the information and many other magic features.

The idea of this practical CAAD model is trying to take the advantages of both architect and computer, making them work together effectively in the interactive optimization design cycles in which the architect makes the decisions and the computer makes the design analysis and comments to assist architect making decision in the sketch design phase, which could improve design quality, reduce building cost and raise up the design productivity.

The working process of the CAAD model is quite simple. Compare with the traditional architectural working process, a layout database, a data collecting and two feed-back cycles are added. These are the main parts the computer assists in the model.

The diagram of the model is shown as following:



A design database in the model contains many of design layouts or unites with the same building type, working as a design layout reference library. The database management system works like a skilled librarian, it can search the database according to the design requirements and find out the reference layout units for the designer.

In the design-editing section, a design will be created or modified with an architectural specialized drawing software package which can fit fully with the architect drawing needs, so that architects can work on it freely and easily to create or modify a design with high efficiency.

In the data-collecting section, various design attributes, indexes and criteria regarding to the quality and standard of a design will be recalculated or collected, which will be the base for further design evaluating and item analyzing.

In the design-evaluating section, the specific design parameters, indexes, attributes and criteria are evaluated by a built-in design knowledge base, checked with the design core, senior architects design experiences and specific design criteria and standards.

The results of this section are a series of comments and parameters, just like a professor gives the comments to a student's design, which point out the direction for further design modification.

In the design item-analyzing section, a collection of several design criteria analysis software in which single design criterion will be analyzed or simulated qualitatively and quantitatively, such as function criteria analysis, technical criteria calculation, building cost, natural ventilation, lighting, energy conservation etc. In terms of function criteria, two kinds of objective function involved will be calculated and analyzed for a design layout arrangement: a spaces relationship matrix objective function or a functional circulation line objective function of a design.

In the working process, two feed-back interactive optimization cycles are the main course of the model. The design editing, data collecting, design evaluating and then design editing again....., that forms the first cycle. And the design editing, data collecting, items analyzing and then design editing again....., that forms the second cycle.

The architect, according to the design requirements and given conditions, may access into the layout-database section first and picking up reference layouts from the database automatically which meet the needs of the design project and then modify (or create) the design layout in the design-editing section and form a building layout drawing file. Computer analyzes the drawing file data and reforms them into design indexes, attributes and criteria in the data collecting section and evaluates the building design in the evaluating section or analyzes design items in the analyzing section. And then, go back to editing section to do the further design modification. These two working cycles can be kept going over and over again until making the final decision with satisfaction. The whole process is called interactive optimization design process.

Obviously, the architect plays first important role in the whole design process and the computer is only an architect's assistant or a design tool.

This model is suitable for setting up building type based on CAAD system different building type would have different layout database, knowledge base and use different items for analyzing and calculating different objective function value.

A 3D Housing Design and Analysis System, as a sample, is based on the CAAD model mentioned above. In that system, the design database consists of two sub-databases, an Apartment Layout Database and a Housing Function Unit Database.

With the traditional housing design approach, architect manages 2D layout plan first with the rooms required. In the 3D design system, architect uses 3D housing function units instead of rooms as the basic cells of a design in a 3D graphic environment.

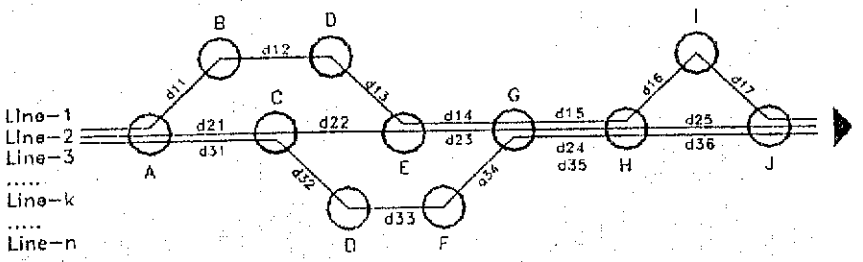
A house for living, that contains many different living functions in it, sleeping, cooking bathing, recreation, reading, TV watching.....etc. Certain amount of spaces are needed for each living function in a house, the spaces for equipment, furniture, and suitable spaces for people's activities. Each function unit has its specific needs for privacy, atmosphere, lighting, temperature, sanitation, energy, quietness.....etc. So the living functions or function units are the base of a housing design.

In the system, a housing function unit database is created, in which the units are classified with different function type and design standard. At the beginning of a design, the designer should choose the function units from the database according to the design requirements and standard, classify them into groups, make some of the units which have close relationship together to form combined function units and then add partition walls to form rooms and at last form an apartment layout arrangement.

There is a unit relationship matrix built in the system indicating the degree of relationship between units in database, which is the guide for the designer to work with in layout arrangement. Also, it is the base for the related objective function calculation and analysis in an optimization cycle.

The form of Function Unit Relationship Matrix is as following:

	Unit 2	Unit 3	Unit 4	.....	Unit j	.....	Unit n
Unit 1	C12	C13	C14	.....	C1j	.....	C1n
Unit 2		C23	C24	.....	C2j	.....	C2n
Unit 3			C34	.....	C3j	.....	C3n
.....				.....	.....	.....	.....
Unit i					Cij	.....	Cin
.....						.....	.....
Unit n-1							Cn-1n



CIRCLATION-LINE ANALYSIS

$$Fc = \sum_{i=1}^{n} \left(Wi \sum_{j=1}^{ki} Dij \right)$$

In the matrix, the coefficient Cij value stands for the degree of the relationship between Unit1 and Unitj. It quantitatively stands for the importance of the relation between function unit (i) and (j) in the whole housing design arrangement.

The objective function value is calculated as:

$$Fobj = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} (Cij \times Dij)$$

where : Cij — relationship coefficient between Unit i and Unit j.

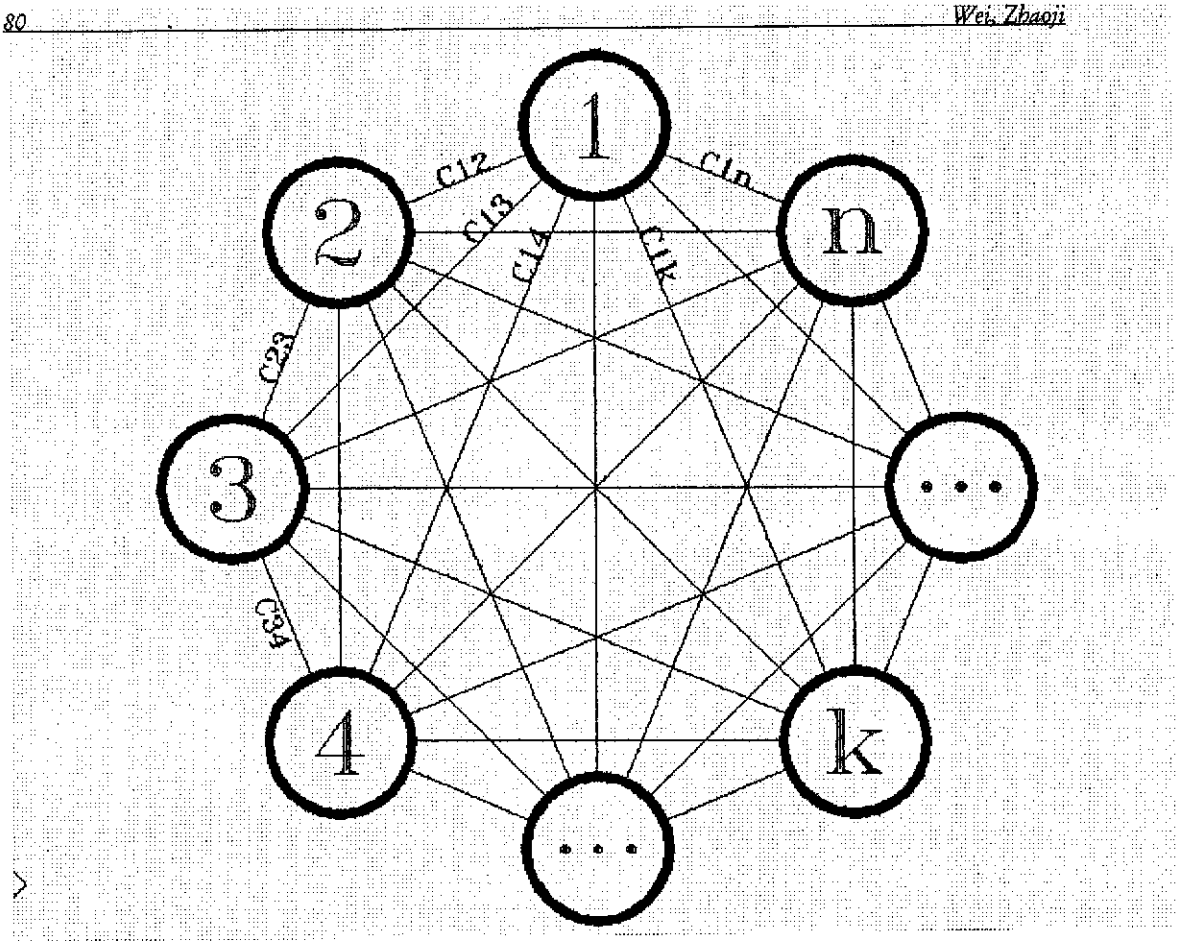
Dij — calculating distance between Unit i and Unit j.

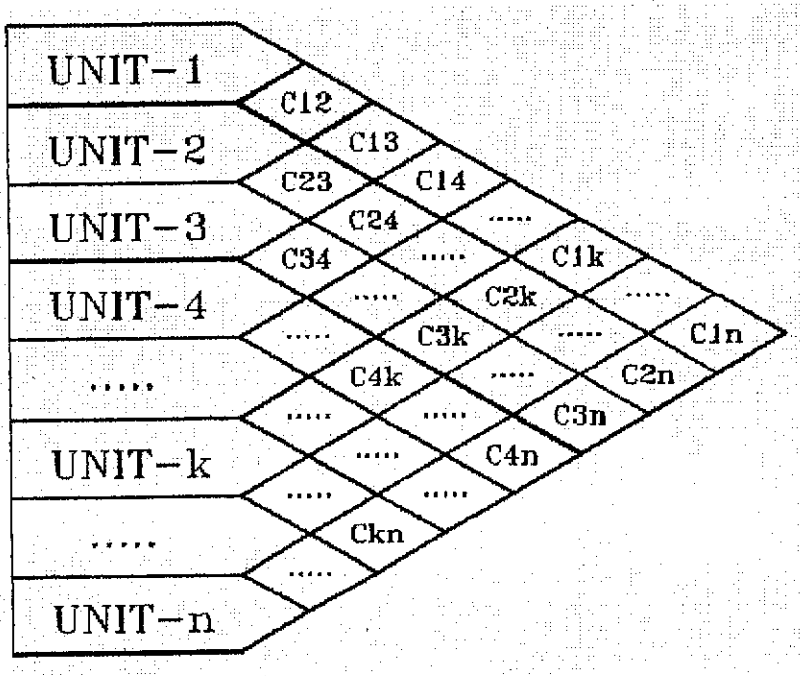
The Cij values are already made in advance by the system developer based on analyzing the function units attributes and the statistic work. And, the specific Dij values will be calculated or picked for a specific design in the data collecting section of the system automatically. The smaller Fobj value means the better quality of the design arrangement. The system can also analyze and print out the comments for a specific design layout arrangement for further modification.

The housing design knowledge base in the system includes the content of housing design core made by Ministry of Construction, the standards for housing design in China, a collection of experiences of Chinese architects for housing design and some specific housing design criteria for controlling design quality. In order to make the system work, the collecting section of the system should collect all the data and parameters needed for the evaluating section and analyzing section.

The 3D Housing Design and Analysis System is still under developing. And, we have developed a Computer Aided Housing Design System (HSCAD) in 1990 with the same idea of the model.

May be, this CAAD model is only suitable for the building types which construct in a large scale, like apartment building, or the types which is more functional or technical, like hospital. May be, this CAAD model is only useful in the developing countries. But it is a practical CAAD model. We hope that it will be a useful tool for architect during decision making in the sketch design phase.





RELATIONSHIP MATRIX ANALYSIS

$$Fr = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} (Cij \cdot Dij)$$