CAAD-seminar Rotterdam

Decision models in the design process as a basis for computer-aided design.

Held on January 9th by T. Maver.

Man/machine attributes

The first illustration I want to refer to (Figure 1) is an attempt to compare the performance of machines and man, so that we may begin to identify what part of the design process man can best undertake and what parts are best left to the computing machine. The key attribute is that of reasoning. We see the machine is good at deductive reasoning and man at inductive reasoning. The significance of this for the design process is that man, from a set of observed information can produce a general law, e.g. with a number of observations of pressure and volume man has been able to induce the law PV = constant, the gas law; the machine is less able to do this, but given the gas law PV = constant, it can produce a pressure given any particular volume. This is the key to the attributes of man and machine: whether or not we are at an inductive or deductive stage of the design process.

The design activity

Having looked at the attributes of man and machine, let us look at a model of the design process. The second illustration (Figure 2) is one suggestion for what the design process looks like at this point in time: we have two dimensions, one dimension which is the same as in Jock Campbell's illustration, i.e. the sequential stages in the design process.

These are the stages in the RIBA plan of work, going from the very general to the detailed stages of the design. In the other direction we have a number of activities which are called analysis, synthesis, appraisal and decision. I will say a word or two about each of these in turn.

Analysis is taken to mean the collection of information, its sortation and collation, and the attempt to predict one variable from the level of another variable: in other words, everything that has to do with the inception of the brief in design.

Synthesis we refer to as the creative act, the generation of a design solution.

Appraisal is the activity of measuring and evaluating a design scheme. If one measures it, evaluates it and discovers that it is inadequate you return and modify your solution, reappraise perhaps, and so on, until you are satisfied that at this stage of design you have an adequate or a good solution. If this is the case, you take a decision and proceed to the next, more detailed stage in design.

The vertical dimension is a linear, non repetitive sequence and the horizontal dimension tends to be a cyclic, iterative set of procedures. What I propose to do, by way of example, is to deal with a single computer application to building design in each of these three procedures, and to draw some conclusions in relationship to Figure 1 to determine whether or not we are applying the computer at the most appropriate stages in the design process.

Analysis

First of all I am going to discuss an example of an analytical application in building design. Let us take the situation where you have a large number of variables (Figure 3). These may be functional relationships like the need for car-parking, the need for adjacency, the need for children's play-areas, or they may be an actual list of

spatial elements. A cross in the relationship matrix in Figure 3 indicates that a relationship exists, i.e. that there is a dependency. You can redraw this relationship matrix in a slightly different form, by letting a node represent a variable and a link represent a cross. You get a linked network as we see in Figure 4. It is a very simple matter in this case to identify that you have two primary subsets of the problem here. One can draw a circle around each of them and say: this looks like an almost self-contained problem; it is reasonable to deal with these as separate problems. However, if we've got a very large number of variables, perhaps several hundreds, as you will have in a real design situation, the ability to divide the problem up into smaller subsets is extremely tricky, but it is a kind of activity that the computer can perform extremely well. It can structure a very complex problem into a number of subsets which are easily manageable. This is one use of the computer.
There are a number of existing computer-programs slightly different in character, which can perform this kind of function. They are very effective in use and they allow us to reduce a massive problem with very many variables into a number of manageable subsets.

Synthesis

Now an example of the use of a computer to engage in the act of synthesi i.e. the use of a computer to actually generate or create a design solutio The example I am going to give you relates to the design of a university campus in Scotland, and it is one of the programs the unit that I work with has developed. It was primarily a site with a lake in it and some rather nice tree belts (Figure 5) and the problem was to place a number of university buildings on this site. Figure 6 lists the university buildings: arts building, science building, arts/science building, residences and so on, and the matrix represents the relationship which exists between each and every building on the campus. The problem is to place these buildings on the site taking account of the conditions of the site and of the relationships which exist between the buildings. We want the computer actually to generate, to decide, a design solution. For this to be possible, both design criteria must be in numerical form. We have a numerical representation of the relationships and in order to make the site numerical we place a grid over it (Figure 7) and to ascribe to every cell in that grid a value appropriate to how suitable that part of the site is for building on. You can see the lake has value 0, and where there are the tree belts that we want maintained, we also have the value 0; where we have a nice suitable part of the site, we have a value of 10. These values you get from the site analysis.

The program operates by placing each building in turn on the site such that the sume of association values and site values are maximised. Figures 8 and 9 illustrate two solutions, one referring to a 3000 student campus, the other to a 6000 student campus.

Limitations

Before we go on to the third type of application, that of appraisal. I want to say some general things about the two kindsof application we have just discussed. Undoubtedly the analysis stage is certainly a very appropriate stage at which to apply the computer: the arrangement of data and its statistical manipulation is very effectively done by the computer. The kind of processing one wants to do at the analysis stage as a building designer is, however, very similar to the kind of processing all other people engaged in design want to do: civil engineers, mechanical engineers, psychologists. The same activities of analysis exist in architecture and building design as in the other fields and a great many suitable programs already exist. (For instance, time-sharing computer companies have many statistical programs available for subscribers). So our effort as program developers is not most effectively applied in developing analytical programs, because these will be developed by other people.

The research that we are doing at Strathclyde does not relate to the analytical stage. Neither does it relate to the synthesis stage, and this is for a quite different reason. Although one can persuade the computer to generate a design solution, it simply does not do this kind of activity very well. When we compare man and machine attributes, it is clear that the machine is not good at pattern recognition or at manipulating a large number of disparate variables in order to converge on an optimum design solution.

This is in my opinion the least effective way to use a computer and I shall come back to this a bit later.

Appraisal

Let us proceed, then, to the activity of appraisal in design which, in my belief, is the most effective stage at which to apply the computer. Now what we have to imagine here is that we are going to describe a solution to the computer and it is simply going to measure and evaluate it, so that we can either return and modify our solution or decide to adopt it and process to the next stage in design.

At this werkseminar I demonstrated a program called PACE 1 which is an appraisal package applicable to the outline proposal stage in design; one can imagine PACE 2 applicable to the scheme proposal and PACE 3 applicable to detail design. Briefly, I want to refresh your memory about what this package did and then to draw some fundamental conclusions which it was not possible to do during the demonstration. You may remember that we imagined the designer having a design concept for a school and that the machine led him through a process of data input. It asked him questions which allowed the machine to obtain a description of the scheme. It asked him about what type of building it was, where it was located, and so on. It asked him about the geometry of the scheme, the shape of it; it asked him information about the site, and it asked him information about the construction of the building. Finally it asked him about the relationship matrix which existed between the components of the building. When this had been done, the computer was then able to produce for the design team a number of measures, or appraisals of the scheme: a) capital cost, running cost, heating cost and so on, b) spatial performance, which is how the scheme relates to the site, c) environmental peformance, which was really the sizing of the engineering servicing plant which was required in the building, details of the heat loss and the heat gain, and finally, d) what we call an activity performance which measured whether or not the relationship matrix was satisfied by the geometry of this particular design solution. There are one or two points I want to make about the output of this package as an appraisal tool. The first is that we can use such a tool as a way of developing a data bank of information about building design. You see from Figure 16, which is the computer output, that we have results for this particular building in the column headed "VALUE". We also have what I call a "UNIT VALUE": we divide capital costs by the number of occupants in the building to produce a cost per person. Once we have standardised unit values, we can then, if we wish, store information about this design in a data file, so the next time we come to design a school, we have got a set of information about it, and in the column headed "MEAN" we can bring back out of file all the information we had about the previous school. The third time we design a school, we can refer to the mean of the two previous schools and so on. So that each time we use the package we are doing two things: we are updating the data file and we are bringing forward into the program a more sophisticated set of cost and performance data on school design. So there is a two-way exchange within the data bank: automatically upgrading and getting back larger ranges of previous solutions. The mechanism is valuable in that it helps us to generate and build up design experience because the key of the design problem is deciding whether you have got the right mixture of performance on all these measures and others that are not on this particular program. For instance is the investment right for the kind of performance you are getting out? This is the crucial business of design: deciding where you have got a multivariate objective function just to what extent you are satisfying conflicting objectives. When Nigel Cross was talking he mentioned the concept of a solution team, bringing the client and the user back into the design activity. I would like to suggest that this kind of mechanism - very explicit appraisal - is the perfect way of doing this. It is possible, from the very first moment, for the designer to suggest a design solution, to give the client this output, so that he can decide, rather than the architect, whether the level of monetary investment is sensible in relationship to how the building isggoing to perform. He can see if he thinks that capital or running costs are too high, or that building 3 is too far away from building 5 and so.on. And this hopefully will cause the architect or the design team to go back, and when the computer asks the question "Do you wish to change the layout", he will change it according to how the client and the users have responded to the output performance of this particular building.

But there are some other significant uses of the program which may bring about changes in design attitudes. One is that the clients - at least sophisticated clients - when they recognise that one can be explicit about performance specifications, are going to start giving architects or design teams briefs containing performance specifications

You see, building design, as we at present know it, is very different from other fields of design in this respect: if one wants to order a boiler the client does not say: "I am not prepared to pay any more than 40.000 guilders for a boiler, see what you can do", he comes to the designer and says: "look, I want a boiler, I want it to raise so many pounds of steam per hour, I want to have a flow temperature of so many degrees Fahrenheit", i.e. he gives a performance specification to the designer. The designer then attempts to meet the performance specification at a minimum cost. The interesting thing in building design is that it is the other way round. The client comes and says: "Look, I want a building and it must not cost more than one and a half million guilders", and then he does not know what he is going to get back for his money. Now if we can be explicit about performance, then I suggest that the sophisticated clients are going to produce a very detailed performance specification for a building and it would then be the design team s task to generate a scheme that satisfies the performance specifications at a minimum cost.

Now we have talked about appraisal but we have not said anything about how the architect or the design team arrivesaat this initial proposal for design. If we imagine thatall design solutions lie on a single dimension between bad and good (Figure 11) then, if you have got an effective appraisal mechanism, it does not matter where on this dimension your first proposed solution lies, because the appraisal mechanism allows us to go back and modify it, so that we make one jump along the line, and then we modify it again and again, until hopefully we converge on an optimum solution. The only difference that the starting point makes is perhaps the number of jumps it takes to come to the optimal point. So it may not be important how we produce this first approximation: either by the rational method that we saw for the planning of the university campus, or by ecclectic processes, (i.e. stealing somebody else's design, as I am sure we all do as designers) or by a purely intuitive process or, indeed, by a completely random process.

We have got a rather interesting study which is being conducted, oddly enough, by undergraduates of Strathclyde. There are four students in the group and each of them is attempting, for the same design problem, to arrive at a solution in these four different ways: intuitively, ecclectically, randomly and systematically. Then they are going to use the PACE appraisal mechanism to see whether or not these four quite different approaches result in the same solution, i.e. to establish if all solutions do lie on a single dimension between bad and good.

The other important point about an appraisal mechanism like this is that it can be used either for the design of a specific building, or as a researc and development tool. Let us imagine that in your office you wanted to investigate the relationship between heat loss and daylight. The relevan laws of physics are extremely complex, and the only way to begin understanding the relationship between these two variables is in fact to systematically vary the fenestration in a number of solutions, keeping the other design variables constant, and to simulate what the daylight factor is and what the heat losses are. From the output of the program runs, it would be possible to establish statistically the functional or causal relationships between the variables which we manipulate as designers. My suggestion is that a program like this gives the opportunity for us to do basic development work which simply is not done in architectural offices in the United Kingdom.

Research and Practice

Within our university organization we have a unit called ABACUS, which stands for Architecture and Building Aids Computer Unit, Strathclyde.

We are attempting to do two things: ABACUS STUDIES is with teaching and research activities, and ABACUS SERVICES provides a consultancy to architectural offices in the matter of computer-aided design. One of the interesting things I wanted to say about our structure is: the response one gets from undergraduate students. We have only been engaged in computer-aided architectural studies at Strathclyde for three years, but already in our final year some 75% of the students are using computers in their final year design projects, and using them effectively . A lot of the program development and the reseach work is, in fact, undertaken by undergraduate students. It seems to me that this is a healthy thing. But if it is healthy for society, it is a bit worrying for the profession, because these students are going to come into the profession expecting a rational approach and computer facilities, not ten years from now, but this year, next year. I do not think the profession is ready for them. There is going to be a tragic mismatch between these students and the partners in the practices.

I am surprised that you should think that more is happening on the CAAD scene in the United Kingdom than in the Netherlands. I think it is a wrong impression in many ways. For example if we organized a similar conference to this one, we would perhaps get half of the number of participants. So I think the attitude of the profession here is better, judging from this conference.

I am not at all pessimistic about the attitude of architects or about the future of computer-aided design in architecture. I agree with Nigel Cross when he says that as a profession, we may have an advantage in that we are holding discussions, symposia, and conferences like this one so that we can be prepared for the disadvantages as well as the advantages of the computer. I have always found - I am not an architect - architects emminently sensible. They might not have used computers at the earliest possible time, but when they do get around to using them, they will use them perhaps more effectively than any other profession.

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