Plastic modelling - the flexible modelling of the logic of structure and spaces

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ABSTRACT
"Plastic Modelling" is a technique which allows the computer model to be easily developed and manipulated. In particular it models not only building geometry but also logical relationships between elements, components, structure and spaces. It is the author's contention that this approach to solid modelling is particularly suitable for the interactive development of architectural design ideas.

BACKGROUND

For many years the developers of Architectural Computer Modelling Systems have been promising better design as the result of the use of their systems. The promise of better design stems from the idea of better feedback from the model about the performance of the proposed building in every aspect, including cost, structure, environment, organization and appearance. The implication is that% on the basis of feedback at an early stage, the designer will modify the design and continue this process in an interactive manner until a satisfactory solution has been derived.

This idea of the design process begs many questions and in particular does not reflect the way in which designers normally work. The author has argued elsewhere and (Frazer 1979), will continue to argue, that it is not unreasonable that the Computer Aided Design process might well modify the current architectural design process on the grounds that the present process leaves much to be desired. But, this should happen by intention rather than by default as is occuring at the moment.

Different modelling systems suffer from different faults but they often include the problem of allowing only a restricted vocabulary of geometrical forms to be input - or more subversively, they allow a limited set to be input easily and other geometries may require a very great deal more effort. The author regards this as Computer Obstruction Design (COD). (2) There is the associated problem that not only can it be very tedious to input the building description but it is the very precision of the information demanded from the designer which in effect requires the building to have already been fully designed. At this point, far from being an aid to building change the model has become merely an aid to visualization, and thus it is being reduced to a mere presentation technique to the client. Furthermore if the designers does, as a result of some feedback, wish to make changes then these changes can themselves be very difficult to make to the geometrical database. This is Computer Inhibited Change. Far from encouraging change the statistical data provided by the model merely becomes extra material for the defence of the design. This is Computer Obstructed Criticism.

Plastic Modelling

Despite the reservations expressed above the author does believe that architectural computer modelling has a significant part to play in the improvement of architecture and design. It can also significantly assist the design process itself, but in order to do this it has to be approached with a different technique to that used so far in architectural modelling.

This technique is referred to by the author as "Plastic Modelling". (previously referred to as soft modelling (Frazer 1986)) Essentially it implies the use of an alternative geometrical input manipulation technique which allows the geometry to be inherently easier to change. In order to do this it is necessary for the geometrical data base to contain significantly more information than is currently the case with traditional solid or surface models, but this information facilitates rather than inhibits change and can be of a form other than strictly geometrical data. In particular, this new technique makes use of **relational operators** which establish logical and spatial relationships between elements as well as strictly geometrical relationships. This gives the design process an inherent logic and structure which continues to make sense of the geometry after significant changes have been made. This is accompanied by **design development motes** which are in effect the history of the development of the design along with any associated characteristics to do with process. Again this implies that the design process can be re-run with the equivalent of a **rethink function.** Another aspect of the database is that of a **process modeller** and this again has significant advantages in terse of making sense of the relationship of the built form and the building process and again has advantages in terms of things doing subsequent costing.

Furthermore, this technique employs a new approach to the modelling itself. Instead of using the more usual surface modelling or constructive solid geometrical systems this approach sakes use of space occupancy modelling which the author believes is more appropriate to the modelling of architectural type forms.

DATA MANIPULATION

The starting point is thus the author's contention that for any modelling or drafting system to be useful to a designer it must be easy to manipulate and change data - hence plastic modelling. It must allow a mode of interaction which is close to the way the designer thinks and more to the point it must understand the logical relationships between decisions that the designer is making - hence relational operators. It must use a mode of interaction which uses terminology familiar to the designer - designer vocabulary. (I have carefully avoided the word language as in Shape Processor Language as this still carries overtones of a computing language and all that implies in terms of mode of interaction. What I am referring to is specifically the choice of words and hence the use of vocabulary). The system must understand the thinking process and the sequence which the designer went through - design development notes. And thus the opportunity to have the equivalent of a rethink function which allows one to rethink and change significant design decisions whilst maintaining the consistency of the relational operators. Alternatively it is possible to maintain the sequence of thinking but to change some significant relational operator.

Extended Database

All this implies a database very much richer than that encountered either in traditional drafting systems or traditional solid modellers.
It is not longer adequate to have a merely geometric database that knows about lines and their location in space or just about surfaces or just about solids and their geometrical location. The database must he expanded to include the logic of the spatial or constructional relationships between the parts and why they are where they are expressed in relational terms. For want of a better phrase I have been referring to this as "object modelling". It is also essential for the model to move away from a level of geometrical abstraction and understand the processes relating to the discipline

to which it refers. In other disciplines such as Mechanical Engineering there has been an increasing tendency to develop geometrical descriptions or modelling techniques which bear a close relationship with the manufacturing technique which is subsequently to be applied. Thus, for example, the description of complex curved surfaces in terms of parameters which lead easily to the description of complex tool paths for machining. On the whole I believe this sort of thinking has not been carefully applied in the Civil Engineering and Architectural fields. Having a modelling database which does understand the process of construction has two major advantages. First there is a tendency for the system to most easily describe forms which are indeed constructable and second, it should be possible to not only extract costing information on the quantities of materials used but also information about the nature of the process being used to place them.

Additional Uses of the Database

The author takes it for granted that it would be possible therefore to access such a database to get very different kinds of information. Not just as at the moment to provide drawings or indeed as a basis for performing calculations or extracting information on quantities, but for example, it should be possible to extract from the database an animated sequence of the processes to be undertaken on site in the order which they will have to occur, as for example, to extract those processes relevant to a particular trade.

Another advantage of such a database is that it allows us to take advantage of features of solid modelling such as clash detection without having to pay the overhead in either computing power or user data input of a full solid modelling system. I refer to this technique as space occupancy modelling. This phrase is related to, but significantly different from, the concept of modelling which is normally known as spatial enumeration or sometimes even spatial occupancy enumeration (Requicha 1980). This technique implies dividing all forms into minute cublets rather like three dimensional pixels on the screen. It is a technique well suited to certain geometrical forms or disciplines such as tomography but carries an astronomic computing overhead for the more general or complex surfaces and leads to problems of resolution.

It has been pointed out by Lionel March amongst others that because of the rectangular and regular geometric nature of much building a simplified version of spatial enumeration technique might be applicable to architectural form (March 1971). Once free of the obsession of dividing structures into cublets then it is possible to conceive of a hybrid technique which uses appropriate geometrical descriptions rather like special primitives representing normal building elements whilst at the same time exercising the rigour of the checking for spatial occupancy which other models utilize. The result of this is a model which is non-ambiguous, is extremely simple to construct, has very economic storage, is rapid of calculation, is easy to manipulate. It also allows the relational operators the process modelling and the design development notes previously mentioned.

A further significant bonus with this approach is that it is then possible to use the component of this database as a primitive in a finite element analysis package thus given the strict non-ambiguous description of the geometrical forms, plus the logical relationships in the modeller plus the understanding of the process and the jointing of structural forms. It is then possible for a designer knowing nothing of the structural calculations to take advantage of a finite element analysis of a structure during its early development stages and to get immediate feedback on the stressing and sizing of members at an early stage. Robin Clarke at the University of Ulster has demonstrated the feasibility of this technique and has shown that substantial savings can accrue (Clarke 1987).

A PROTOTYPE PLASTIC MODELLER

Autographics have written a modelling system based on the principles expounded above. The project team was managed by Julian Fowler and the program was designed by the author. A version of the program for the education market was launched in October 1986 by **British Thornton** as part of their compas range - **Compas Designer.** This first release was specifically aimed at product design in the education sector. A more advanced version of the program **Design Modeller** will be launched by **Autographics** later this year. This will be aimed at the environmental, architectural and construction markets.

The User Interface

The system is menu driven. The user environment looks like a windows type screen, but is in fact **FACES.** The name 'Faces' was chosen in order to underline that the user environment, or face of the program which the user encounters puts on an appropriate face for the discipline of the user. So for example, a module of the program dealing with joinery contains words like: mitre, scribe, tenon, etc.. This means that although the actual operation may, in computer terms, be the same, an appropriate word is used for the discipline to which it relates.

Relational Operators
Relational operators allow the user to specify a relationship between components such as wanting one edge to be parallel to another, two edges to be parallel, one component to be centered on the other, one to remain flush with another. Figure 1.

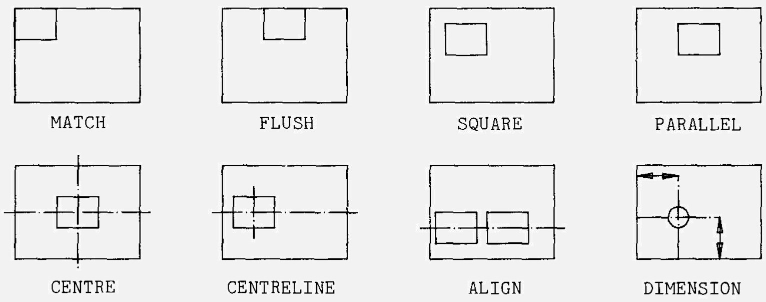

Figure 1. Examples of relational operators.

The significance of this is, that if at another stage, some component is changed in its location, all the other related components will change to logically have the right relationship with it. Thus it is possible to specify that two columns will be aligned irrespective of one of them being moved. So if one of them is moved, the other will always move with it. Figure 2.

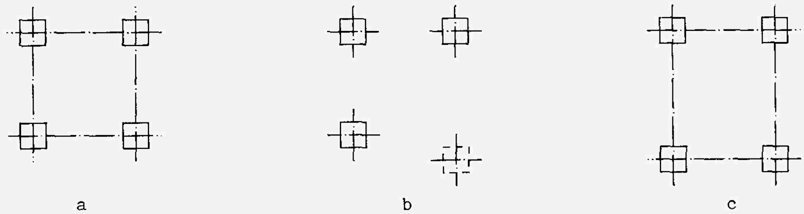

Figure 2. ALIGN - The relational operator align has been used to specify the relationship between the column (a) so if one is moved (b) then the aligned column will automatically be moved (c).

alternatively one could specify the partition is always flush with the column, even if the column is then move, the partition will move with it. Or it could be centred on the column. Alternatively, and possibly more significantly, it is possible to change the relational operator so that you can say that every partition that was flush with a column is to be replaced with a partition which is centered on a column then this operation will then be performed all the way through the relevant assemblies automatically. Figure 3.

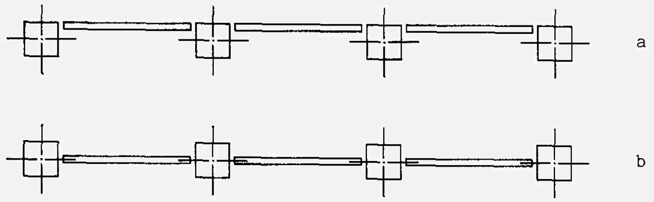

Figure 3. **Flush** replace with **Centre** - Every operation flush with a column (a) will be replaced with one **centred** on a column (b)

Rules can also be established for fitting. So for example if the column sizes change the partition size is automatically changed. This can all be given priority. So for example the column spacing could be made dependent on the partition size. Figure 4.

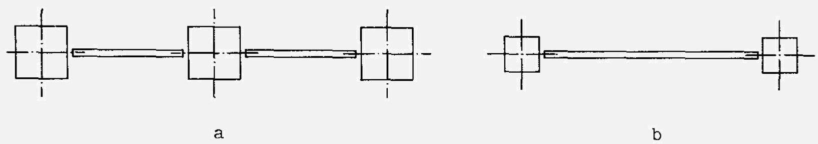

Figure 4. **FIT** and **PRIORITY** - If the partitions are specified to **FIT** the column spacing and subsequently the column changes size then the partitions will be re-sized to fit (a) alternatively if the column spacing is specified to fit the partition then the column spacing will automatically change to fit the partition length (b).

Multiple Operations

It is possible to also apply more than one relational operator, so for example, it is possible to specify first of all that something should be flush with something, then secondly that it is perpendicular to something else, and thirdly has a particular dimension. If a contradiction later emerges then the system will unwind the operations in reverse order and attribute highest priority to the operator first applied, then flag the user that it is going to break one of their rules due to some inconsistent liter change.

Technology of Discipline

A further sophistication is that the system knows about the technology of the discipline with which it is operating. So again to use timber as an example, when indicating that you wish to join two timber members, these are first classified into S groups of junction types. These are based on a classification by Eastwick-Field and Stillman (Eastwick-Field 1956). For example:

Group 1 - square or flat sections joined at right angles, as in the head and style of a door.
Group 2 - flat sections joined at right angles as in the construction of a bookcase.
Group 3 - flat sections joined at right angles as in the framing of fitments.

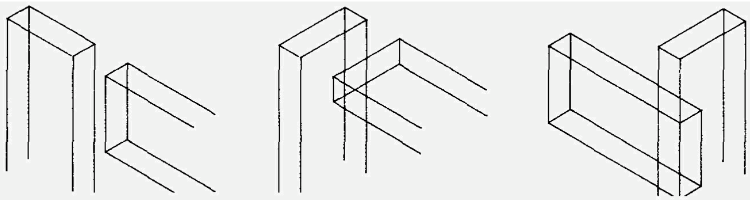

Figure 5. Automatic jointing - Examples of joint classification by group types.

A sub-menu then appears showing the range of joints that the system knows about for the particular specification. The menu might be, pinned mortice and tenon, through mortice and tenon, open or slot mortice, t-bridal, snub tenon with continuous grove, double tenons, twin tenon, twin double tenon, bare face tenon etc. Figure 6.

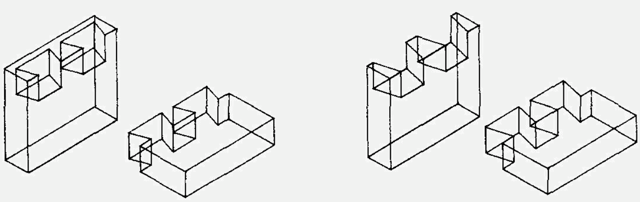

Figure 6. Automatic jointing - Examples of appropriate joints for the group type.

Having selected the required type of joint the system will then automatically add those joinery details to the component description.

CONCLUSIONS

I should also like to conclude by asserting that at last the time has arrived when systems are going to be available which not only draw what has already been designed, or model what has already been drawn, but actually begin to assist the design process. We have not yet moved to systems which work at the inspirational level, or the meditative level (Frazer 1984). But at least we have started to make inroads into the manipulative database area where genuine alternative strategies can be experimented with at a design stage without recourse to detailed geometrical descriptions, and at the same time being sensitive enough to the building environment, the designer's intentions and the concepts of spatial organization to begin to make a useful feedback to the designer during this critical early phase in the design of a building.

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