INFORMATION-BASED REPRESENTATION PARADIGM

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ABSTRACT

This paper presents an "information-based representation paradigm". The objectives of this modelling paradigm are based on the premise that:

- Process is inseparable from the product;
- Information is collected and captured from the very early stages in the procurement process, including the design brief (program). Many early decisions and design intentions must be captured and made known to the future managers of the facility;
- It is imperative that we addresses the issues of buildability and building quality (performance and its measurement);
- A building is considered as an organic growth process: information thus grows as the product develops from its embryonic stages, to full growth, to adaptive re-use, and to decay; and
- Information modelling is 'continuous' over the building life cycle: not piece-meal to address the various disparate requirements.

INTRODUCTION

Models are currently used mainly to facilitate assembly, and are developed in a form recognised by the on-site constructors. Not surprising, then, that for most constructed facilities - including buildings - very little or no information about the facility is available a few years after it has been built; often, not even drawings. The other class of models is for the analysis or design of individual parts of a building. Thus current modelling paradigms also consider a building primarily as a technical solution to a very complex set of human physiological and socio-psychological needs. Thus in the building process, traditional modelling approaches merely represent the hardware components.

We do not seem to have a clear statement of the objectives of modelling. Building representation is largely seen to be synonymous to data modelling relating to the building plans and perspectives. For example, an important objective is that models should be such that they can be used to measure building performance (quality and buildability) before it is built. This important objective behind the modelling movement (started by thinkers such as Markus, Eberhard, Manning and

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Bruce-Archer, to name a few) has largely been forgotten or given a back seat.

MODELLING

This is hardly the platform for a discourse on modelling, but we must understand the basic approaches to modelling - and thus the use of models - before we can talk about modelling for the construction industry. The main approaches, as classified by Vemuri (1978), are:

Direct Modelling: This is used for problems where the system is completely specified, such as a 3-D description of a building to be studied for wind stresses, and we wish to determine the unknown output (the stresses due to wind forces) given the input (the level of wind forces). This can take the form of a physical model to be tested in a wind tunnel or a mathematical simulation. This is what we understand as the 'analysis' problem.

Inverse modelling: This is applied to synthesis or design problems where both input and output are specified, such as the level of forces (load) on a beam and the maximum level of stresses and deflection allowed due to the load. The problem is to determine the system characteristics (the beam cross section area) that would work under the given levels of input/output.

The 'modelling' problem: The term 'modelling' is normally used to find a description (usually in the form of a mathematical model) for a real system (existing or a working prototype) which is expected to function under a given set of inputs and outputs. The nature of the 'process' within the system may be completely unknown; the model is only expected to give the correct output in response to a given input. Thus the system model is valid only for those sets of inputs and outputs for which the model has been tested, and does not have a general validity. This approach can be used for systems which can be defined completely by a formal or symbolic procedure; such systems are governed the laws of physics.

Building models: In building design we use both direct and inverse modelling, albeit for parts or smaller sub-systems of the building which have a simple and well defined structure. In most of the traditional design work we take the Leibnizian approach ("Truth is analytic") that a system can be decomposed (for the purpose of analysing and/or designing constituent parts) and recomposed (aggregated). For much of such analytical modelling work in buildings, we require a geometric description of the parts of the building to be designed or analysed. This geometric description is now popularly known as 'product modelling'.

Product modelling

A 'Product model' is a representation in 2- or 3-dimensions showing primarily the assembly of components, which, for obvious reasons used to be called machine or assembly drawing. It is convenient to obtain from such a representation the schedule of items and quantities in order to estimate costs and facilitate inventory planning. Traditionally thus, in 'Product Modelling' only the end-product, as a prototype ready to be assembled, is required to be represented, since this serves the main purposes of assembly, costing and scheduling. Such traditional product modelling serves the needs of industrial and engineering products well since the end-product, as an artefact built to serve very specific functions, reveals all the basic - generally functional - intentions of the designer when the product is put to the correct use. In such products, be it a clock or a bullock cart, there is little adaptive re-use; unlike in the case of buildings. Thus such product models are rigid since they serve a rigid product (one that cannot be used outside the 'environment' it is designed for, and one that is not going to be put to adaptive re-use). Such models serve an important but limited function.

The models used to analyse or design parts of the building do not constitute the main 'product model'. We thus seem to have models which

- either are used to merely describe a building;
- or which are used to predict the behaviour of individual parts, but do not constitute the so called 'product model'.

A building is not a rigid artefact, and yet buildings are represented using modelling techniques borrowed from the manufacturing industry. Such models are what Eastman (1993) calls state description. But the 'behaviour description', which keeps changing with time - all the time - is rarely, if ever, provided. We believe that models needed to represent a building - as a 'process of change', within the context of the changing environment within which it functions over a long period of time, do not exist. This paper attempts to draw your attention to some of the key requirements of such dynamic representation for a building.

Process modelling

The Beginning

In 1962 Asimov proposed a design methodology for engineering design. Following this, the RIBA adopted the Plan of Work. The various methodologies and 'design methods' proposed in the following two decades were the first attempts at representing the "process" and parts of the process. The basic intentions were:

- To achieve better design quality through a better understanding of the strategic procurement and early design-decisions which have an enormous impact on the behaviour of the end-product.

- To facilitate the exploration of a wider solution space.

- To test the performance of a proposed solution. The convergence on to a final solution to the problem would require that the performance standards are met and trade-offs among conflicting requirements are made until a "satisfactory" solution is found. The "performance-concept", which was evolving alongside the 'methods', had an important contribution to make to this appraisal concept developed by thinkers such as Markus, Manning, etc.

The above list is only indicative, and not exhaustive, of the significance of understanding and modelling the "process" in achieving the desired end-product. In this process various team members have to collaborate and co-operate until they coalesce.

Unlike most industrial products, buildings have a much longer life-cycle in which a building can undergo considerable change of use (function) as well as structural changes. The environmental conditions within which a building is required to operate can also vary considerably during its life span. It is significant to highlight that the 'environment' includes not only the physical factors but also socio-economic and political factors. Therefore the initial design intentions (goals and objectives) and specifications (including the 'total' environment) need to be adequately represented for a life-time use. Any changes in these at any point in the life-cycle must be immediately recorded. The information to be modelled is, therefore, not just about the assembly of components (now called objects) but about the entire "process of change" - from inception to demolition (we shall call it the I-D cycle). Process modelling is thus about the representation of all the information generated and manipulated in the I-D cycle. This would include much important information such as the client objectives, state objectives (environmental and regulatory issues), and user (physical, socio-psychological and economic) needs.

During the procurement and early design decision-making stages, the rationale for important decisions such as the building shape and size, the choice of structural system, etc. must be captured into the Process models. By the very nature of this specification and requirements, no single model can accommodate all the information. A model, by definition, is an abstraction of a real system; that is, only the key parameters are included. The need here is to capture all the information related to the process during the I-D cycle. Thus we are now going to show that a 'process model' for a building process is a misnomer. But first, let us address the question of modelling 'the process of manufacture or site-assembly'.

Indeed, the "process" of site assembly (construction) is an important one, which must be carefully planned so that the assembly activities are scheduled to minimise time and resource requirements and to organise the inventory for just-in-time delivery to the site. It is also recognised that after this process has been properly planned and scheduled, communication among participating constructors is the key to successful completion. "Process modelling", as currently defined, is understood to represent this assembly process. There are adequate tools to serve this so called process modelling such as PERT, resource-constrained programming and GAs. However, such models and tools serve a very definite but limited function during the assembly phase, and have little use after assembly is complete.

Let us then move on to the 'total' building process. Modelling the complete building process (in the I-D cycle), however, requires that all the decisions that have a bearing on the building life-cycle are captured and represented. A "building process modelling" is one that evolves continually till the building is demolished. The need for modelling arises because we want to monitor and control the entire process.

PROCESS CONTROL

We would like to propose, first, that there are no suitable representation paradigms to 'model' and 'manage' the construction process. Also, we take the position that the process that we need to address is the entire I-D cycle in the life-cycle of a building, and henceforth we shall call this 'The Construction Process'.

The management of this process is essentially a complex task of 'information management'. It is well known that the members of the design team (all those involved in making decisions at any stage of the process regarding any part or whole of the product - including the client or state representatives) have to search thorough many diverse and vast sources of information. What is not recorded is the enormous amount of crucial information that should be part of the product model. Such information would include: client objectives, state objectives, user needs, rationale behind all procurement and design decisions, designer's intentions (or semantics, as they say), events of compromises, and so on and so forth. The Building Performance Research Unit (Markus, 1972) recognised that objectives are an important and inseparable part of the product (building) model. The Unit's model -called the BPRU model - was the first true attempt at a process model since it proposed a framework to capture time-based information for controlling the process.

One of the very crucial aspects of early decision making is conflict resolution: that is, trade-offs have to be made since not all needs can be met optimally ('The sum of optimal sub-solutions will never be an optimum'). All decision makers must therefore recognise all needs and all constraints, and must collaborate and coalesce. This collaborative and co-operative decision-making environment cannot be created unless the entire information used in this process can be captured and made available to all members.

The members of the design team, however, do not work concurrently, contrary to what one current paradigm suggests. If various members are working simultaneously (as the term concurrent suggests) to arrive at the solutions to the respective parts they are designing, these parts will not fit together. The process is in fact recursive: decisions regarding one part have to be matched with other parts and, if required, compromises made. This is one-to-many causal mapping (Parrot optimisation), which can be achieved, but concurrent problem-solving requires many-to-many causal mapping which is too complex.

Such process information is thus an inseparable part of the end-product. This information virtually describes the decision-making process. Sadly, what we know today as the product model is the bare minimum assembly drawings - a jumble of 2-dimensional lines with some numbers! Most building owners can't even find the drawings a few years after the building has been handed down to them.

Since the process continues (I-D cycle) throughout the building life-cycle due to changes needed for adaptive re-use, the most useful information - as listed above - is never made available to the client, owner or manager.

Be they complex economic decisions made during procurement stage, or geometric manipulation during design (spatial) synthesis: all are acts of information (data and knowledge) manipulation. Spatial synthesis, for example, is an act based on information synthesis, such as "If we swap room X with room Y, this will result in reduced noise in X and more light in Y", etc. Information manipulation precedes the action of spatial manipulation. In this 'information synthesis', aesthetic criteria may also be included, which will come to light when the geometric manipulation is complete.

It is imperative that we know the "conditions" under which these economic and functional decisions have been made. This is because, at any stage during the process, when a change becomes necessary, these prevailing conditions must be known, so that a comparison can be made with the anticipated 'future' conditions and the necessary corrective measures (for change) can be taken.

The Process Control Manager

It is abundantly clear from the above discussion that the building 'process' - as defined and described above - cannot be captured by any representation schemas that could be termed a 'model'. In this complex task of information management, what we need is suitable frameworks to capture all the information during the process, store it in a form to maintain its integrity, and make it available throughout the process for any kind of decision making regarding in the built-environment.

Since this process is dynamic, the Process Control Manager (PCM) must be open ended.

During this continuous and evolutionary process, the building - as an open system, undergoes countless number of changes. Changes are indeed taking place during inception, design, and assembly. During the operating life changes are made due to changes in needs, environment, or objectives - individually or collectively. An important role of the PCM is to provide - at any point along the time frame (such as t_i) - the current state of the product ('the product model'), the current state of the environment, the current state of constraints (including objectives, criteria, needs and values), and the current behaviour. This current state will be a result of the cumulative changes in the environment and the constraints that have taken place from inception (t=0) till the 'snapshot' time, t_i. Thus it is important to know what the sum total of these changes are, and how exactly these took place. The PCM will thus have to keep a log of all the changes - an onerous information management task indeed!

CONCLUSION

We do not as yet have any model to control the development cycle of a building - a model that can be controlled and manipulated with the aim of understanding the behaviour of the (total) system and in order to predict its (the building's) behaviour - now and in the future.

What we have today in product models are purely descriptive models (such as a CAD database) which provide us with a lot of data but little information and contain absolutely no knowledge about the building (as a living system) or the complex process that it goes through not just during its design and delivery phases but throughout its life-time. The designers central to controlling this process merely retrieve the necessary data, feed it into other analytical models and make decisions about the next step! This is like working with a computer with a memory but no processing (control/communications) unit.

What we need is an information processing manager that can support the functions of a 'Process Control Manager (PCM)' described above.

Operationally, the architecture of a PCM will have access to the project information-base and the geometry information-base all the time; however large or small; integrated or distributed such databases may be. During various stages of design and procurement, it will need to access many other (distributed) databases to support the many (little) analytical functions.

We must note that technology driven models, such as the ones we use today, will not serve the needs of managing the building 'process' unless we develop the information management frameworks which enable us to control this process on a continuous and dynamic basis.

REFERENCES

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