Design Data Acquisition For Building Simulation

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ABSTRACT *There is increasing concern and awareness of the contribution of the built environment to global environmental problems such as the depletion of the ozone layer, large-scale soil erosion and deposition, the generation of greenhouse gases, atmospheric hygiene and surface water quality. Me dispersion of refrigerant gases from air conditioning plant, urban stormwater run-off, the energy requirements of space heating and lighting, and waste management and disposal are all significant issues in the impact of buildings on the global environment. They are also complex issues that are not easily modelled and managed with conventional skills and design tools. What is needed is a new approach to ign and design information that takes advantage of current technological and cultural change.*

These are some of the issues being canvassed in the design of new accommodation for the Australian Geological Survey Organisation (AGSO) in Canberra. The 40,000 square metre new office and laboratory building is a pilot project which develops an approach to large scale building design and site planning embodying ecologically sustainable design principles, and which demonstrates that an environmentally sound approach can be commercially successful, functional and attractive.

AGS0 is a scientific and technical organization with field, laboratory, and office based activities in support of the acquisition and maintenance of geoscientific data of significant importance -especially to sectors of the Australian economy such as the mining industry. The accommodation facilities they require are correspondingly complex, technical in nature, and of importance in the success of the organization's activities.

The design focus is on ensuring future flexibilily for the changing needs of a dynamic organization with diverse research and commercial programme requirements, and on the responsible management of energy use, resources and environmental impact. The foundation of this flexibility is a design database system that allows for the continued use of design data in the dynamic management of the facilities. An integrated, computer -based design, construction and building management systems approach is under development, in support of the building design processes. It uses an object methodology to specify and generate design data that is relevant beyond the design phase of the project.

We believe it is the future of Computer Aided Design technique in the construction industry, and the beginnings of a solution to handling the complexities of environmental options for building design. It is the relevance and impact of this approach on computer simulation techniques for buildings that is the theme of this paper.

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The Building

The AGSO building design approach to thermal performance uses passive techniques which account for ambient conditions, thermal mass, insulation, high levels of daylighting and natural ventilation.

The design proposal is for a building which comparably consumes substantially less energy, with the balance of energy input needed utilising cogeneration principles and local storage of energy in heat sinks and sources such as groundwater thermal exchange. This approach has obvious benefits for global environmental concerns such as concentrated greenhouse gas emissions at thermal power stations. Resource strategies to minimise local environmental impact include collection and re-use of stormwater and greywater on-site, solid and liquid waste management, and minimisation or elimination of pest and vegetation control chemicals. The pursuit of these goals in combination with the complex user requirements for the new building set a design, construction and management task that demands an innovative and effective approach at every stage.

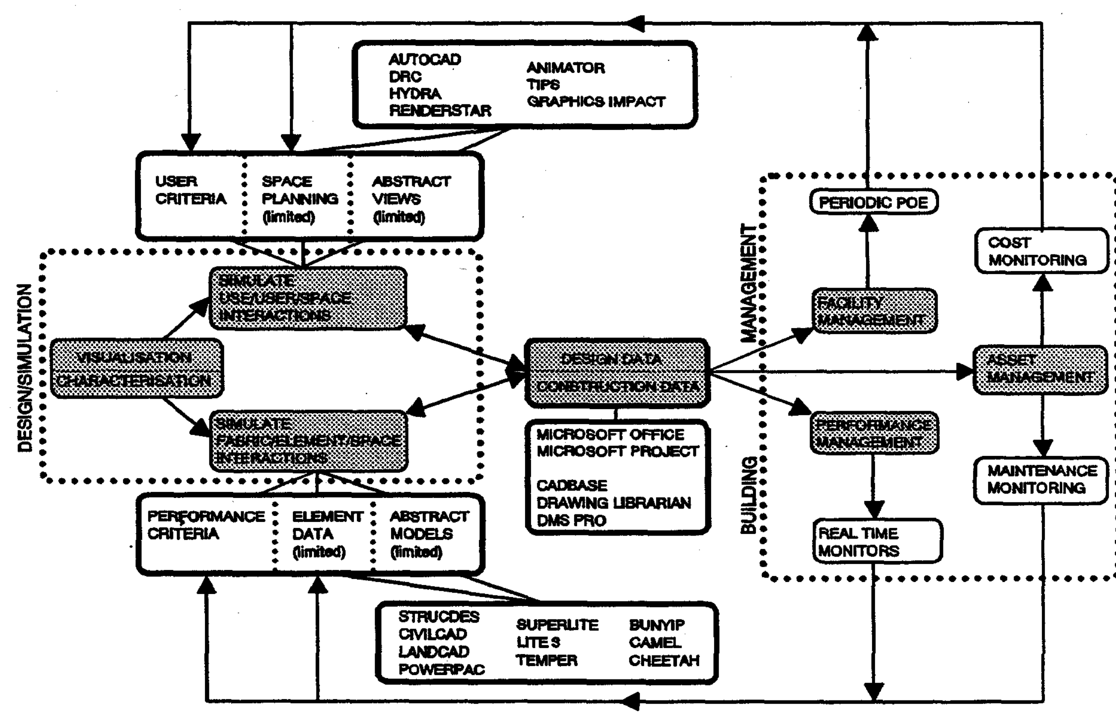
Design Practice

Typical architectural project design appears divided into two main areas of activity, both of which involve varying degrees of modelling and simulation. These activities are the visualisation of the building design, and the characterisation of its performance.

Visualisation should be an interactive process with the building client, especially if the client is also the building user. It models those spaces in the design that are important to the use of the building, and should simulate and communicate the proposed usage patterns of those spaces to draw out the design issues and options to be resolved. There could also be concern about the aesthetics of the building form, and the implications for a personal or corporate image. The better the modelling and simulation aspects of the visualisation process are realised, the better that communication and resolution process should be.

Characterisation is concerned with the performance options for the realisation of the design form. It is the process which models the interaction between the elements and the fabric of the design, and the spaces they create. The models used in this process are usually mathematical abstractions which deal with the generalities of this interaction, and which use elemental data that tends to be generic for a given element type. The accuracy of this approach to characterisation is seldom tested to margins that are close to its limits, because the resulting models are then fitted to construction codes of practice that bury the results in a considerable margin of safety. Simulation studies which rely on better element data and mathematical statements that better describe the

FIGURE 1 **Design and Simulation Life-Cycle**



behaviour, or the behavioural differences in elements, will obviously result in more accurate performance characteristics.

The simple process flow diagram (*fig.1*) illustrates an analytic view of the interaction between these two streams of design and simulation over the life-cycle of a building. This view forms the basis of our approach to structuring and manipulating the project design data. The diagram also indicates some of the software tools currently used by the project, and where they are applied.

The Team

Visualisation is often associated with architectural design, and characterisation with engineering analysis and design. These activities are even executed in isolation on many projects.

A multi-disciplinary Project Team has been established by AGSO to design, document and manage the construction of the proposed new accommodation. The Team skills span architecture; landscape architecture; interior design; laboratory management; structural, mechanical, civil and electrical engineering; industrial design; building science; quantity survey; project management; and computing. Each skill is typically represented by just one person. A small team environment provides opportunities for cooperation on aspects of design that are not found in typical large, sequential design efforts. The information and data exchange needs of this group are the first consideration in the development of a computer-based design methodology.

The Approach

Conventional design information has been shaped to communicate the needs of that design to those who will realise it in the construction process. The quantity survey, construction management and financial management activities of a project are often poorly served by raw design data. Similarly, asset management activities which flow from the construction process and require maintenance schedules, recurrent cost models and life-cycle indicators, are generally poorly served by conventional construction data. A computer-based design methodology by its nature operates in a medium which facilitates better communication between these activities, and should address their information transfer needs. That information should be in a form that can be used as part of a building management system.

The Project Team undertook a systematic evaluation of AGSO accommodation requirements using statistical survey and interview techniques, and a participatory design approach. The identified functional requirements have undergone a number of critical reviews by the Team, and by representatives at all levels of the AGSO. The Team itself contains members of AGSO staff. The resulting design brief and indicative layouts are a highly detailed record of the user and building requirements. This document is viewed as dynamic life-cycle information, to be used and amended by the AGSO as appropriate. It forms the basis of the facility management part of the building management system.

Conventional engineering analysis tools do not usually yield good performance predictions for the physical characteristics of a building. The emphasis has been on ensuring that those predictions fell within agreed or regulated limits to a given order of accuracy. Compounding this situation has been a lack of monitored performance results from the built environment itself. If the environmental cost of buildings is to be reduced then their performance has to be more critically evaluated, and appropriate adjustments made.

For the AGSO building, the Team will undertake simulation studies of the fabric and elements of the design to test its effectiveness against the performance design criteria. From these studies they will develop more accurate performance models for the building, which will be used with real-time data in the completed project as the performance management part of the building management system.

Design and Simulation

Project design criteria have been established from the initial AGSO user brief and from the sustainable performance goals for the new building. These criteria form the basis of a set of logical views of the project design database, to be used for the evaluation of design decisions. This is seen as a means of optimising design efforts that encompass a wide range of considerations from functional, architectural, and environmental, to financial, social, and cultural. The objective is to model, simulate, and record as many aspects of the project as is feasible and reasonable in the computer medium, during the design phase of the project.

For visualisation this means that the building form with its detail and fittings are all 3-dimensionally modelled and correctly scaled in the CAD environment. This provides form data that can be used for massing studies, shadow simulation, site analysis, spatial analysis, lighting simulation, and interior design studies. Most current computer simulation in support of these activities is derived from abstract models with symbolic output records. These are difficult to understand or communicate across disciplines; they are virtually impossible to use when dealing with project clients. Accurate, extensive 3-D modelling of the designed form provides the basis of rendered views, simulated pass-thru, and real-time spatial analysis. Virtual Reality techniques which can simulate movement through interior views of a virtual building are much more comprehensible to the building user than sparse symbols on a 2-D plan drawing.

For characterisation, the design system requires that all the necessary physical attributes of the modelled elements are accurately related to the element geometry, and are correctly scaled in consistent units. This provides element data that can be used for structure studies, energy simulations, and services analysis. The challenges in this arena are the extent of attribute data needed for accurate simulations, and how that data should be structured for universal access by the appropriate analysis tools.

At each stage of the design process, the data generated needs to be in a form that can be used directly for other design and simulation activities. To achieve maximum efficiency from design data generated in the electronic medium, it should also be applicable to processes involved in the operation of the completed project. The relevance of design data beyond the design phase is only guaranteed if that data is rich in real attributes, and not simply a disparate collection of abstract characteristics. This implies that modifications or additions to the design information that occur during the construction phase of the project need to be comfortably accommodated by the project database. Similarly, the issue of accessability to other designers and constructors during the life-cycle of the building means that the data needs to be open in structure, as well as relevant.

If these needs are met, then performance parameters and models derived during design can be applied directly to the operations of the building over its life-cycle. Operational data derived from both real-time monitoring of the physical performance of the completed building and from the evaluation of maintenance, facility usage, and cost management strategies can be acquired and used to refine the performance models. Better models can then be applied to the live project and to new designs.

Design Objects

To create design data in a re-usable form, the AGSO Project uses a definition of design objects that mirrors real-world objects, and incorporates information about them in a design database. This information is segmented into graphic data and attribute data. The design system uses a CAD environment to generate and manipulate the graphic segments of model objects. These graphic descriptions are incorporated into database records in a form that is indistinguishable from object attribute data such as physical properties, cost and maintenance statistics. This data forms the attribute segment of an object.

This allows any part of the object geometry to be *related* to any part of the attribute data . This is in contrast to the conventional CAD/database mechanism where the complete graphic data set for an entity is *associated* with the complete attribute data set. This associative mechanism does not permit the formation of arbitrary, valid relations between the geometry and attributes for a design entity. While it is possible for the relational CADbase mechanism to attach any member of an attribute set to any level of geometry, it is not useful to give extensive attributes to graphic primitives, which are themselves schematic or abstract entities in the context of designing real objects. What is needed is a useful level of graphic information to which real-world attributes can be attached.

Collections of graphic primitives need to be given definitions that enable them to comprehensively and consistently model real objects. These objects must be constructed in a way which allows all the primitives of which they comprise to be manipulated and characterised as a single entity. Groupings of these entities into more complex compound objects must also show these characteristics, in the same consistent way.

Object Classification

The sets of real-world objects to be modelled need to be examined and typified by some common, abstract definitions. Classification of these object definitions determines the type and degree of attribute information to which they attach. This is essentially a question of object resolution. What constitutes the minimum usable object in design, and for what are its attributes to be used at this level of information?

The AGSO Project uses a classification scheme that is outlined in the simple diagrammatic example of a window (*fig. 2*). Although it is not accurate in a detailed sense, it does illustrate the way in which simpler objects are referenced into more complex ones, usually more than once.

Compound objects need to inherit the necessary characterisics of their component objects so that there is no redundancy of object data. The object class definitions must account for the re-use of component objects in different compound constructions, again without redundency or ambiguity. The definitions must accommodate models of real objects to be used in the construction process, as well as abstract artefacts used in the design and management processes. The assembly process for compound objects is handled in the CAD environment, using an external reference mechanism. This allows for the most natural design process. Attribute data moves with the externally referenced object into the compound construction. It is also possible to construct compound objects using data tables, but this is not a recommended approach.

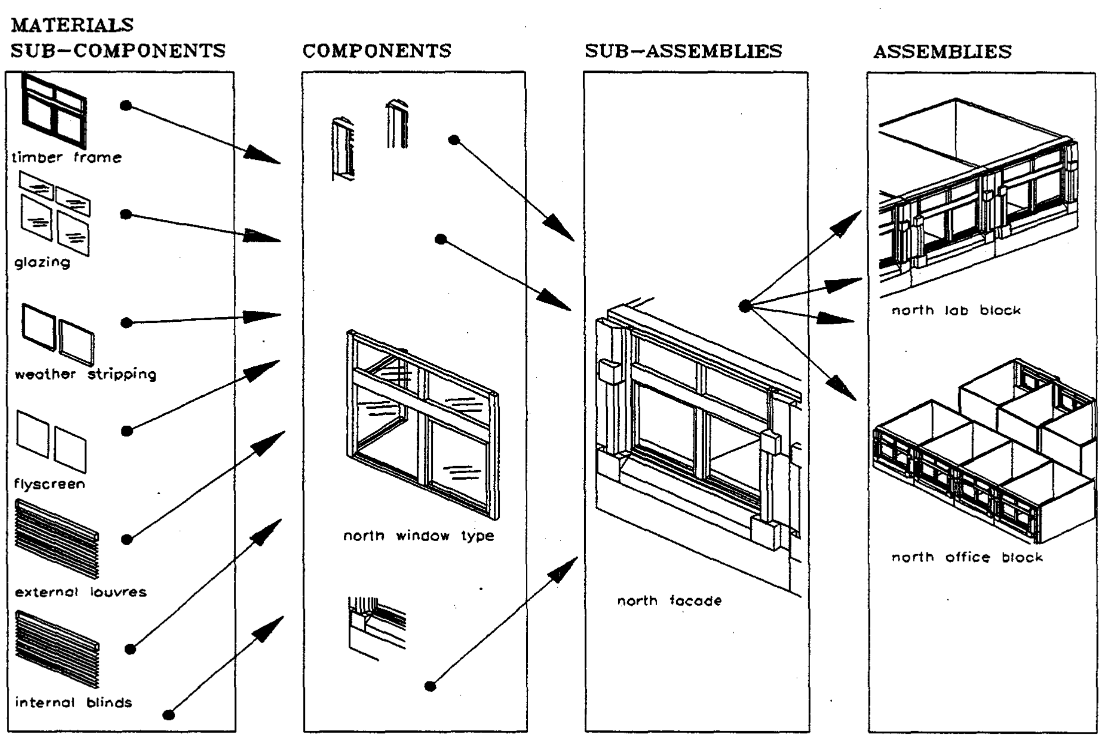
Object Data Relations

The types and relationship of non-geometric attribute data to the geometry of objects is an open question. The penalty of a wide, non-critical selection will be large data storage overheads, most of which could lie idle. However, as there should only be one instance of any particular object referenced many times, this penalty is mitigated to some extent. For example, although there are hundreds of windows in our project, the attribute data for the glazing will only be stored once at the materials/sub-component level.

The usefulness of any particular attribute is difficult to estimate. It depends very much on the type and quality of any analysis and simulation applications that are likely to use the model. The only criterion that can be used at this stage is to establish as many real-world characteristics for an object as possible, since the ultimate goal is the complete machine simulation of building elements and their combinations. We have not yet seen any applications that are open-ended enough to accommodate future increases in the complexity of building data; most simulation and modelling software seeks to do the opposite.

The concentration on only one instance of any design object is a major culture shift for designers migrating from the paper medium, where the proliferation of copies or variants of a particular document is the norm. This attitude has often been carried into the conventional CAD environment, where it has been one of the main sources of error, inefficiency and management overhead.

Design Object Classification **FIGURE 2**



Object Management

As well as object classification and attribute definition, an object methodology for building data needs construction and edit rules, data entry and edit rules, object naming and management methods, data access and reporting mechanisms, and a clear means of establishing to the designer what the object represents in the real world. So why do it?

Without even considering the application of data beyond the design phase of a project, the ability to use powerful and well established relational database management tools for resolution of design conflicts and control of workflow; the fast costing of design options and interactive constraint management by use of on-line references to dynamic brief data, design criteria, and building standards; comprehensive reporting mechanisms and the easy production of contract documentation, is sufficient motivation in itself.

The simplicity of a single object instance multiply referenced is one of the main sources of efficiency in this approach to CAD and CAD management. It means that any elaboration, edit or change to design objects is global, that design effort is not being duplicated, and that revision control is a minimal management effort. The computing system effects are also positive. Storage and computation loads are rational and shared, network and system management loads are balanced, and the correct data is secured for system recovery.

Object Methodology

There are some practical limits to the level at which objects can be resolved and recombined in the current system medium. These are questions only of operational and system resources, and are not absolute constraints on the methodology. In other words, the application of sufficient computational time or data storage capacity to the handling of objects will eventually complete any object operation. This is a situation where performance will always continue to improve with the technology.

In presenting this view of work-in-progress on the AGSO design database, we have concentrated on the methodology and the general issues that arise from using this approach to building design and simulation. The particular software tools and data manipulation methods currently used in the project are likely to change. It is from a thorough understanding of the framework in which they operate that appropriate design and simulation applications can be developed.

However, there is the question of a critical level of object definition in terms of both geometric modelling and attribute modelling. What is the cut-off point where the benefit to design, and subsequent construction and use of that design, is vanishingly small compared to the effort involved in elaborating and operating with that level of object detail? At the moment the only answer to the question of what constitutes a comprehensive building model, is that it is one which can develop over time.

The added benefits to visualisation and characterisation of a building represented by the database are yet to be realised. This is the challenge both for computer systems specialists and building modellers and simulationists.

Conclusion

The design methodology developed for the AGSO Project inherently generates more interaction between the visualisation and characterisation design streams. Designers are more responsible for each others work and have better project data that they can evaluate for complex design alternatives. They are able to address some of the present and future issues of environmental impact and community cost; considerations that are more and more in demand by building users and owners, the community, local authorities, and political decision makers.

These are responsible goals that should be pursued in the construction of buildings at any scale. A major part of the reason that this is seldom the case is the perception of the complexity, and consequent cost of addressing these issues. Conventional building design, construction, and management methods are themselves poorly integrated and coordinated. They are not flexible enough to cope with unconventional building forms and services, and they do not provide a sufficiently simple and economic vehicle for resolving the future issues that confront the construction industry.

The energy use associated with buildings is responsible for more than half the greenhouse gases produced each year by industrialised countries. If we are convinced that what we build should not only satisfy the design brief but be socially and environmentally accountable, then we must accept responsibility for change in the design process. To exercise care, concern and responsibility we need new tools for analysing complex and interdependant relationships, and for establishing a comprehensive design framework.

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Bibliography

Gronbaek, K.; Kyng, M. and Mogensen P. 1992 "CSCW Challenges in Large-Scale Technical Projects -a Case Study." In *CSCW 92 Proceedings* , the 1992 Computer-Supported Collaborative Work Conference (Toronto, Canada, Nov 1992) ACM, Baltimore, MD.

Medina-Mora, R.; Winograd, T.; Flores, R. and Flores, F. 1992 "The Action Workflow Approach to Workflow Management Technology." In *CSCW 92 Proceedings* , the 1992 Computer-Supported Collaborative Work Conference (Toronto, Canada, Nov 1992) ACM, Baltimore, MD.

Maher, M. L. and Saad, M. 1992 "Computer Support for Synchronous Collaborative Design." In Proceedings of *Conference on the Impact of Computers on Design* (Sydney, Aust.,15-17 Nov 1992). Key Centre of Design Quality, University of Sydney.

Gidney, E.; Chandler, A. and Robertson, T. 1992 "Remote Collaborative Drawing for Visual Designers" In Proceedings of *Conference on the Impact of Computers on Design* (Sydney, Aust.,15-17 Nov 1992). Key Centre of Design Quality, University of Sydney.

Olson, J. S.; Olson, G. M.; Storrosten, M. and Carter, M. 1992 "How a Group-Editor Changes the Character of a Design Meeting as well as its Outcome." In *CSCW 92 Proceedings* , the 1992 Computer-Supported Collaborative Work Conference (Toronto, Canada, Nov 1992) ACM, Baltimore, MD.

Trembath, R. 1992 "A Study of CAD Productivity." In Proceedings of *Conference on the Impact of Computers on Design* (Sydney, Aust.,15-17 Nov 1992). Key Centre of Design Quality, University of Sydney.

Marchant, D. 1992 "Computing and Architectural Practice in 1992." In Proceedings of *Conference on the Impact of Computers on Design* (Sydney, Aust.,15-17 Nov 1992). Key Centre of Design Quality, University of Sydney.

Mitchell, J. R. 1992 "The Impact of Computing at the Early Design Stage." In Proceedings of *Conference on the Impact of Computers on Design* (Sydney, Aust.,15-17 Nov 1992). Key Centre of Design Quality, University of Sydney.

Balachandran, B. 1992 "The Impact of Integrated Knowledge-Based CAD Systems on Design." In Proceedings of *Conference on the Impact of Computers on Design* (Sydney, Aust.,15-17 Nov 1992). Key Centre of Design Quality, University of Sydney.

Gigante, M. 1992 "Virtual Reality: 3D Immersive Design Environment." In Proceedings of *Conference on the Impact of Computers on Design* (Sydney, Aust.,15-17 Nov 1992). Key Centre of Design Quality, University of Sydney.

Steven, G. 1992 "Computational Mechanics in the Design Cycle." In Proceedings of *Conference on the Impact of Computers on Design* (Sydney, Aust.,15-17 Nov 1992). Key Centre of Design Quality, University of Sydney.

Spriggs, K. 1992 "Object-Oriented Design of Control Panels via a Visual Development Environment." In Proceedings of *Conference on the Impact of Computers on Design* (Sydney, Aust.,15-17 Nov 1992). Key Centre of Design Quality, University of Sydney.

Mury, T. 1992 "Design of Building Electrical Services Using a CAD Model." In Proceedings of *Conference on the Impact of Computers on Design* (Sydney, Aust.,15-17 Nov 1992). Key Centre of Design Quality, University of Sydney.