10
Information Modelling Tools and Frameworks for the Delivery, Distribution and Management of Digital Multimedia Materials

Peter Ward

A programme of research has been conducted with the aim of defining 'interactive multimedia' – assembling the components of such a system and building working models capable of both demonstrating the idea and supporting a subset of real user needs. The work was born out of a sense of alienation from computers and their operators which stimulated the idea of supporting people within new computer-based interactive environments. It has as a basic aim – the analysis, design and – in working models – the prototyping of general purpose mechanisms for the modelling, organization, distribution and management of multimedia materials.

A working system is envisaged (at first) as a general purpose hypermedia system for the demonstration and refinement of core concepts. Our approach has been to develop working prototypes demonstrating concepts and mechanisms – essentially driven by end-user requirements. We have quickly designed and constructed a small subset of novel 'interactive multimedia'. This approach was elected as an alternative to off-the-shelf solutions. We realized that these were not available and our strategy was to avoid the cost and the overheads of examining and integrating existing and emerging third-party software tools. We chose an alternative ambitious bottom-up software construction strategy – to employ object-oriented technology and an object-oriented top-down design and programming approach. The idea was that it would be feasible in practical terms to achieve real working (and state-of-the-art) models with this approach.

Our aims included the development of a new generation of information modelling tools (Ward, 1994a), the means for authors to design and organize information structures, and to deliver such structured information to 'readers' – through a high quality graphical interface providing simple access and engagement. In our investigation of general purpose mechanisms for information modelling and application building, we wanted to involve 'end-users' in the development process and to explore a variety of subject matter domains including the humanities as well as science, engineering, biology and medicine.

In a number of case-studies a number of applications have been built – all with the idea of exploring aspects of what is involved in designing, delivering and evolving 'interactive multimedia' applications. The scope of applications has covered a spectrum of basic application features and including presentation, learning and publishing. Many of these have naturally borrowed from the environmental context of a higher education

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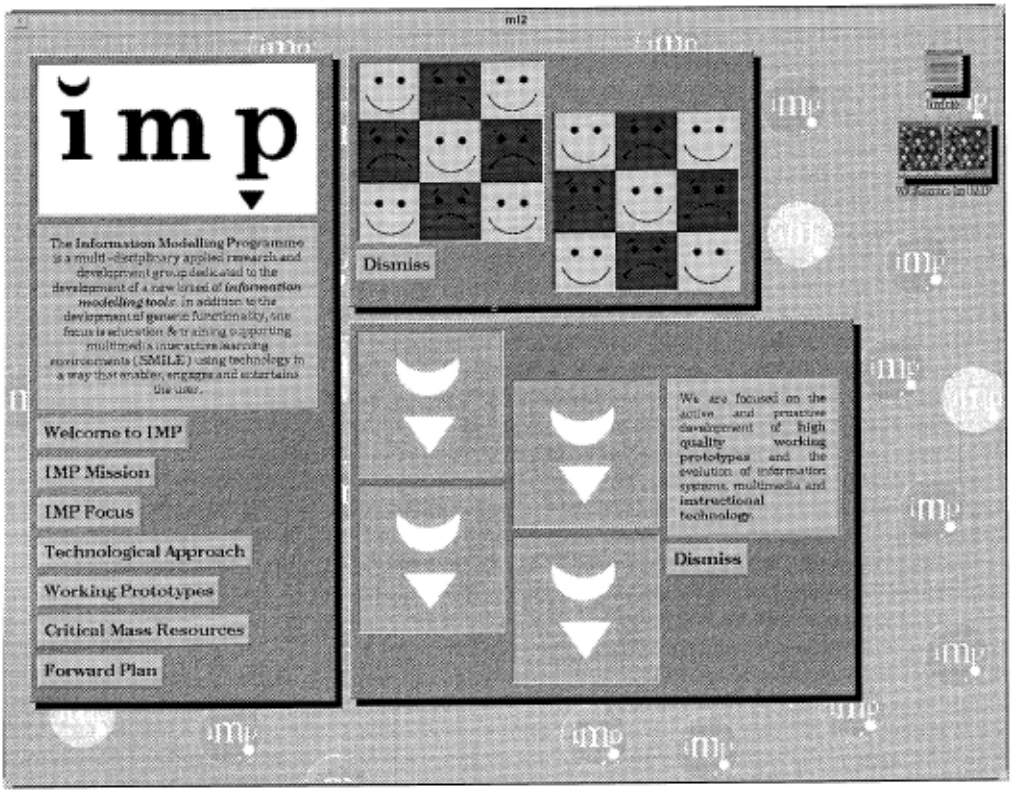

Figure 10.1 IMP: an introductory display.

institute. The SMILE project (Supporting Multimedia Interactive Learning Environments) is part of the general programme with a focus on educational environments and the development of new computer assisted instructional resources on networks. Learning is something we must all do and computers have presented themselves as candidates for a new means of open and continuous learning. Pedagogical interactivity – between the teacher and the pupil – is a type of interaction which requires a number of special processes and features. The SMILE project is focused on delivering this variety of interactivity as a functional enhancement (module) of a general purpose (modular) system. An aim of the educational project has been to implement an 'educational adviser' using techniques of AI and planning (Arshad and Kelleher, 1993). Such an entity has been envisaged as part of a modular system – an 'intelligent agent' – providing a number of services, accessible as an interface component (Ward, 1990, Ward and Arshad, 1992) and linked with an object server for digital documents, with facilities for being organised into various hypermedia structures (Ward, 1994b).

The electronic document is a metaphor for the distribution and communication of digital multimedia materials and a framework for design, organization and distribution. The organization and distribution of multimedia information in 'document form' is a common theme applicable in a wide-range of applications and is a part of a generic hypermedia system. This chapter describes a programme of applied research into building working models of hypermedia – in terms of an evolving series of experimental software tools with the aim of supporting multiple users on a network – and its relation to the evolution of the electronic document.

10.1 Design, Development and Delivery of Information Modelling Tools

10.1.1 A challenge – to enable new means of information modelling and communication, employing the 'best of breed' from emerging technologies

A challenge to designers and developers of tomorrow's information systems is to employ the emerging technologies, to create new means of enabling information modelling, and then to transfer this 'new technology' into the organization. End users need mechanisms that they can easily employ, and the means for the controlled distribution and effective communication of information (multimedia digital data in this context) is a generic need. End users must specify tasks and help to identify processes for which they require support.

The question is frequently asked: is it a case of technologies looking for applications or applications looking for technologies? In the development of new technologies and solutions: are the real tasks being supported (has anyone asked?) and what are the initial perceived benefits compared with the actual benefits (has anyone ever used it?) The next question is: what technologies are best to use; what is the application, what is involved (better still – who will be using it?) Increasingly, rather than selecting and using one or few technologies/tools, the challenge is to identify a variety of 'best of breed' components – and then to integrate them into a working model.

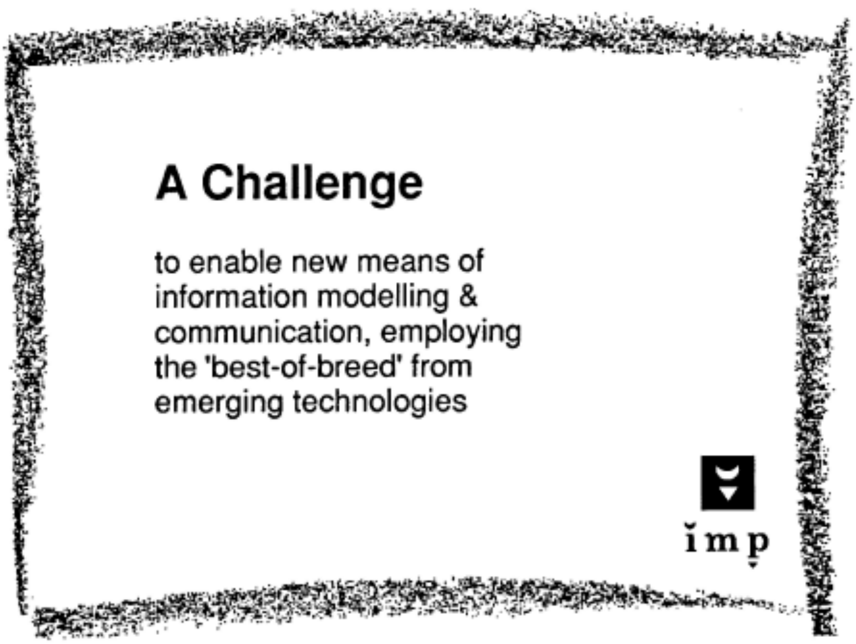

Figure 10.2 A challenge.

Currently there is growing interest in tools for authoring and managing electronic documents leading to the creation of a new means of access for readers and writers. Key features must include good interactivity and support. Mechanisms for controlling access and use (including transaction management, the control of versions and new means of revenue generation) and the management of scale and complexity (including high-level browsers and flexible information models) are called for. Systems should evolve and show emergent qualities.

10.2 The model: people, information, processes, machines and interaction

Underlying our approach to design and development is an interest in the notion of computer-based 'information systems' (as compared with packages, applications or documents). An information system is a complex entity which can be represented in a model. A model is suggested which includes people (first), information, processes and (when required and appropriate) machines. A basic process of interest is communication and the support of various processes of communication – between people, between machines and between people employing machines as a medium for communication.

There are a number of key generic features which are needed in computer-based applications which: (1) provide access; (2) to a varied population of users, who (3) want to model, and (4) to distribute information in (5) all its richness (6) in order to communicate (7) abstract ideas; (8) discrete knowledge, or (9) specific information. The

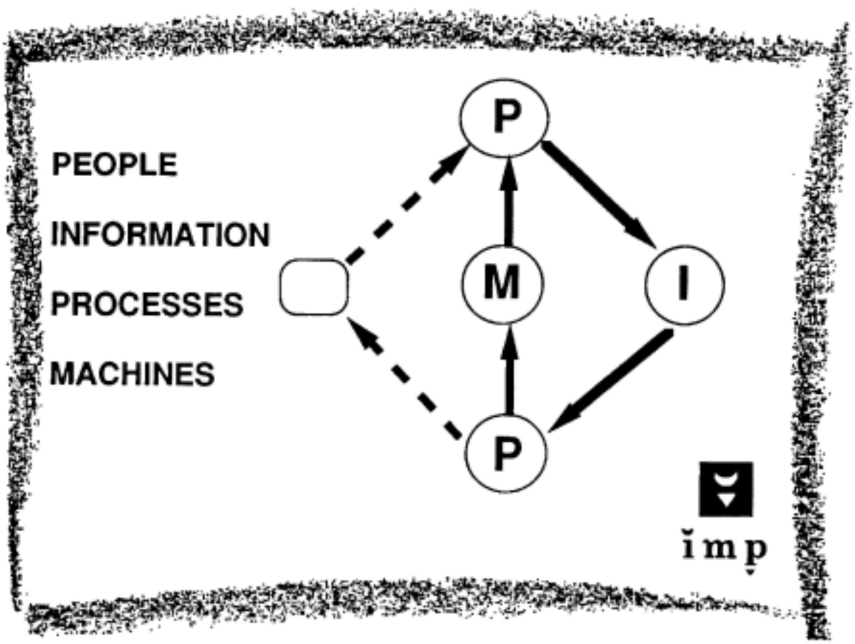

Figure 10.3 The four aspects of a information systems model.

application should attract and engage the end-user and enable a range of basic information modelling tasks such as the creation and delivery of a small or medium-sized presentation–interaction module. It should provide simple-to-use access to digital multimedia resources with a high performance interface. It must support multiple simultaneous users, and provide the means to scale, manage, distribute and monitor an application. We are interested in the prototyping of such systems, in developing mechanisms for the organization and distribution of digital media materials, and the design of new communication structures, e.g. hypermedia documents, graphical user interfaces, browsers and intelligent filters.

10.2.1 People

There is a variety of users of an information system – this includes designers, engineers and developers as well as the so-called 'end user'. The notion of 'end user' is rather restricting and may have led to some technology developments which provide hardly any possibilities for access and comprehension in the user community. In the case of communicators, e.g. in the domains of education or publishing, end users will include teachers and authors/experts/editors of domain materials – communicators, experts in subject matter and material domain modellers.

10.2.2 Information

The information component of an information system will include a variety of digital (data) media types – static: text, graphics and pictures – and dynamic: animation, video

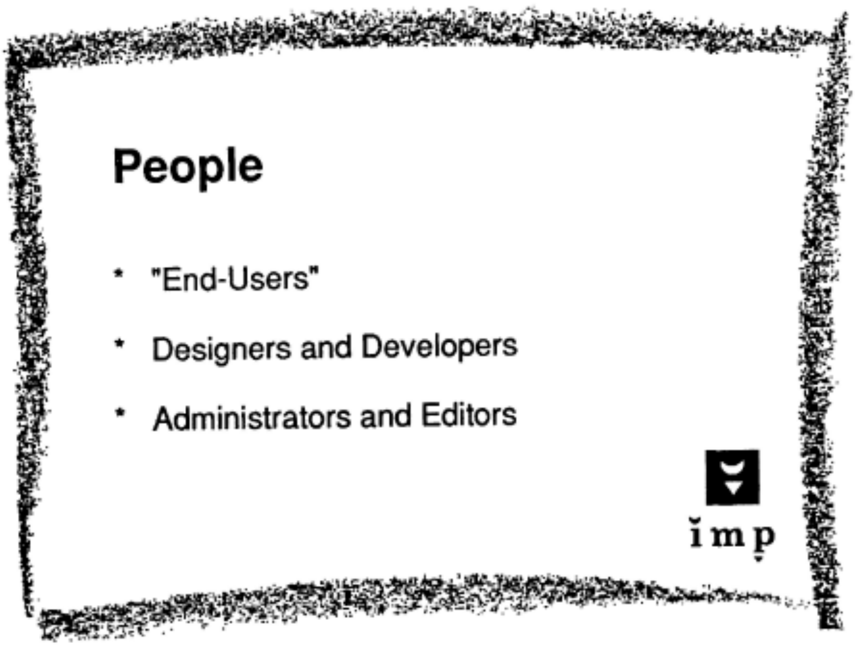

Figure 10.4 People – the principal component of an information system.

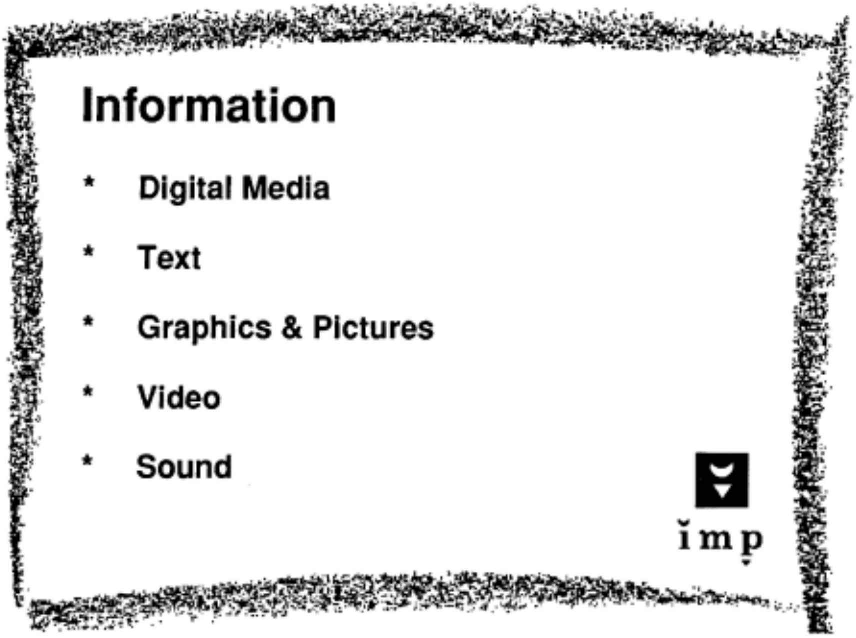

Figure 10.5 Information – content and media.

and sound. As well as data, the database or resource which describes all components of an information system will include the code: the programs which provide the machine with a means of processing the data in the application. Information must be modelled for storage and retrieval and for representation at the application level. Multimedia systems which need to deliver large amounts of material (including audiovisual files with real time and synchronization possible) to many users simultaneously, and in a flexible yet controlled fashion, require a number of generic and general-purpose features and utilities. Bandwidth – for large quantities of digital information to be moved with precision and speed – is a bottleneck. High-quality, high-performance human–machine interfaces will be required – taking advantage of end users' intelligence and compliant with their existing models of information handling and communication.

There is no shortage of information; what is required are better models of systems to deal with scale, complexity and real use – systems which provide simple modelling tools and support for the realization and distribution of a variety of information structures. The 'document' is a conventional paradigm for communication.

Convergence of a number of threads of applied research and of a number of information technologies is a phenomenon illustrated nicely by the notion of 'electronic document'.

10.2.3 Processes

The processes component of an information system includes, at a low level, methods acting on data and events, and at all levels, communication (e.g. of data and

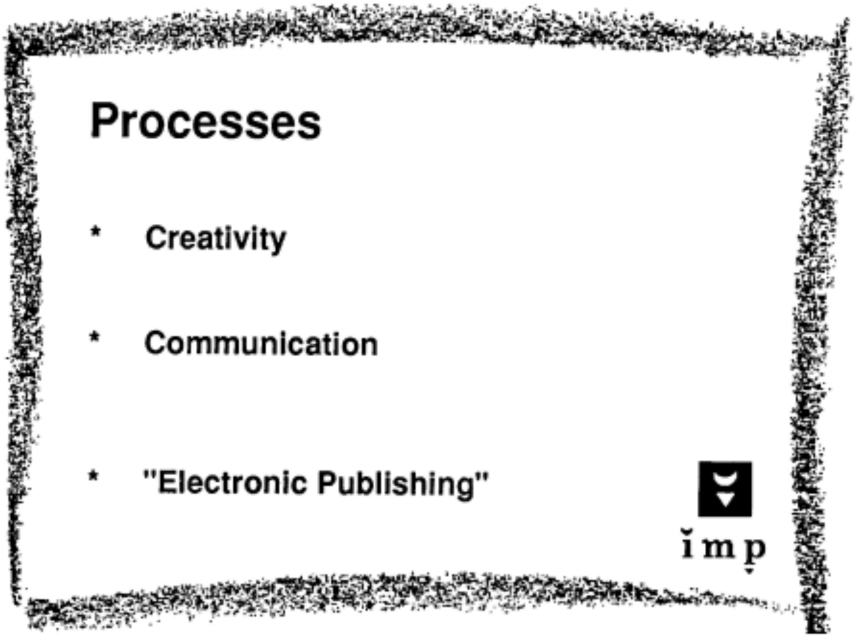

Figure 10.6 Types of process – in an information system.

information structures). Interactivity (between user and machine) and interoperability between system components are processes which must be modelled. The system designed to support end users will need to support a number of processes and enable a variety of tasks and transactions, e.g. data storage, retrieval and distribution and the creation of new versions. The management and control of such processes is a superset which large-scale systems with multiple users will need.

As well as communication, creativity is a basic process which needs to be supported. The sketched idea on the back of an envelope remains a viable and useful mechanism which is very complex to model and support on a computer. By attempting to capture and formalize the mechanisms involved, and working with end-users, designers can provide tools which are stimulating and thought-provoking as well as supportive of the users goal. The realization, organization and dissemination of electronic documents is a complex set of tasks and involves a number and variety of processes.

10.2.4 Machines

An information system need not necessarily include machines, but advantage and value may be added by their inclusion.

There is a plethora of machines (the hardware) which can be used in the configuration of an information system. Generally speaking hardware approximately doubles in performance and halves in cost each year. Making choices is difficult and risky. In the work described here, the principal components include Sun Microsystems SPARC, with UNIX/X11 (Israel and Fortune, 1992), 'C' and the object-oriented programming language Eiffel (Meyer, 1988, 1992).

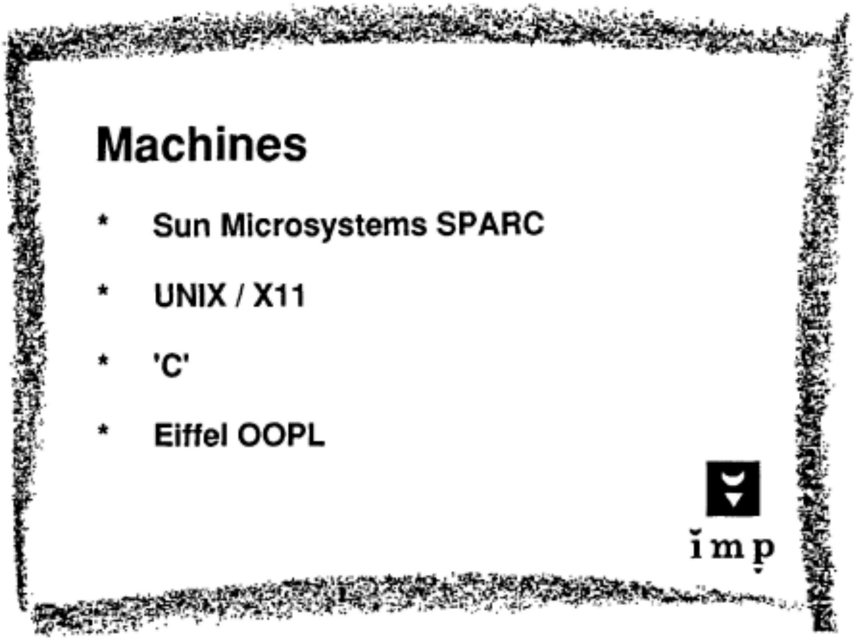

Figure 10.7 Some hardware options – some mechanisms.

There is a significant potential benefit of computer-based systems in a number of domains – including education, financial dealing and entertainment. The fact is that marginal benefits in financial dealing justify substantial investment in new technology, whereas in education, for example, whatever the perceived benefits, nothing like this investment in new technology has been possible. Certainly in terms of 'point-of-interactive-multimedia' there are some very advanced developments in the entertainment and games industry which more than pay back the development costs.

10.3 How?

10.3.1 Rapid prototyping of information modelling tools and components

There are very many alternative viewpoints and strategies in the development of information systems and computer-based applications. These are becoming fashioned by the commitment of the telecommunications industries to the evolution of the next generation of 'superhighways', 'intelligent terminals' and information product and services. Main threads of commercial research and development include support for office documentation, computer supported collaborative working, video-conferencing, design support, electronic publishing and computer-supported tutoring systems. In an immensely complex market-place selecting appropriate and best-of-breed components is a considerable if not impossible task.

A user-centred applied programme of research and development is the theme for this paper. An information technology team (IMP at the University of Leeds) has collaborated with experts from a variety of domains. The aims included exploring the development of new interdisciplinary expertise and new methodologies in information design and modelling, software design and coding; interface design and special types of communication, e.g. pedagogical, in the development of working usable prototypes.

Our approach has been focused on prototyping – attempting to match a subset of user needs with working models acting as usable prototypes. This involves modelling a framework of components for facilitating the organization, distribution and management of multimedia information resources. Rapid prototyping means short time scales between working models with small but significant increments.

10.3.2 Creating a prototype – pragmatics of applied research

We have been pursuing an applied multi/interdisciplinary approach to the development of generic mechanisms and tools for information modelling, presentation and interaction.

In a process of prototyping custom 'pilot' and 'demonstrator' multimedia applications with end users and subject-matter experts in a variety of domains, including science and engineering, biomedicine and the humanities, we have been able to investigate mechanisms for enabling a subset of basic information modelling tasks (Ward and Collins, 1991; Ward *et al.*, 1993; Ward, 1994).

Our aims have included the development of high-performance graphical user interfaces (GUIs), and mechanisms for the support of the acquisition, organization and presentation of information (multimedia materials), with a variety of support for access and interaction. Key generic features envisaged at the outset of the programme of work included attraction, engagement and ease of use.

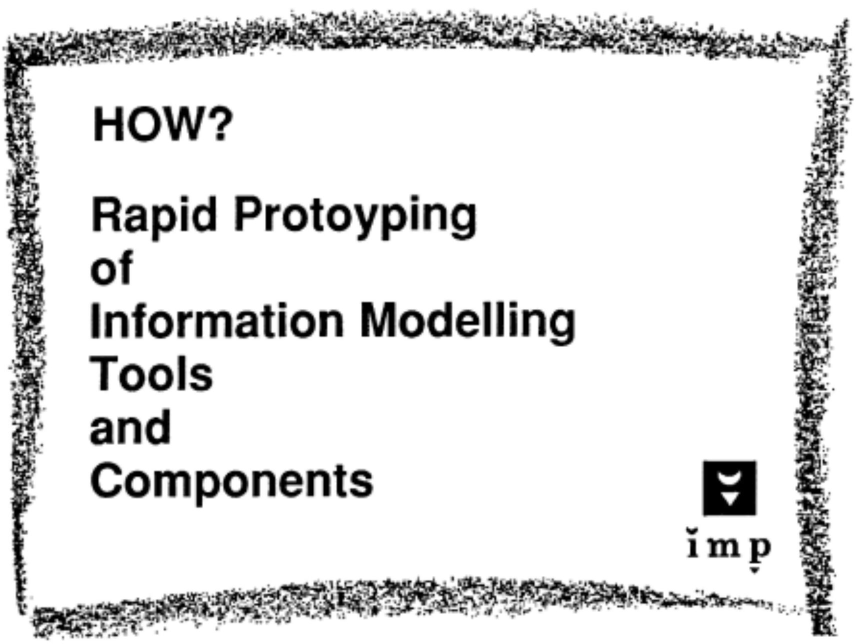

Figure 10.8 How? – Creating a working model.

The 'open systems' approach is consistent with the realities of networks of heterogeneous machines, multiple users, multiple processes, the accommodation of all data types, and the controlled distribution and communication of digital information on the network. In contrast to developments exploiting proprietary and stand-alone single-user technologies and tools, the UNIX multiprocess and multitasking operating system, the portable X11 windows display model, together with the 'client-server computing' model have been employed in combination with object-oriented techniques for genericity, flexibility and portability.

Rather than developing a specific application in isolation which is tied to a particular machine, our strategy has been to engineer components of an application development framework which can become integrated into a modular information system. Such a system would be inherently flexible, scalable and enhanceable, and would provide the means to deliver resources in a variety of circumstances to a variety of users.

Involving end users from a spectrum of application domains at an early stage in design and prototyping is a considerable task. It is nevertheless consistent with prototyping systems which aim to please, and to the development of generic and general-purpose functions. Such functions and features can be factored and refined in response to newly defined requirements. In order to engage end users from any particular domain, it is essential to focus on content from that domain.

10.3.3 Result

A number of working prototypes and tools have been evolved, including a set of class libraries and three higher-level application organization and delivery tools: Graphical Programming Environment (GPE), Media Language (ML) and GARDEN (Parrott and Ward, 1991; Parrott and Ward, 1993; Ward 1994). This has been towards a means to import and then to organize multimedia information (initially text, graphics, and pictures) into high-quality interactive presentations which are simple to use, and thereafter effectively distribute for access to many users on a network.

The first step in our object-oriented approach to prototyping information modelling tools was the Graphical Programming Environment. The 'GPE' is an experimental OOPL, constructed with C++, which provides users with a graphical user interface and a toolkit for the performance of essentially graphical operations – the creation of a user interface and various complex application 'media' objects (Parrott and Ward, 1991).

Buttons, text and pictures were displayable objects whose behaviour could be easily programmed (e.g. a button event as a message to display a linked media item). These objects could be created and manipulated on the screen through mouse selection of tools from a graphical toolkit which could be displayed where required (e.g. create-tool to create a rectangle and colour-tool to colour its border and its background). Applications could be constructed and could be stored as persistent states – to be reconstructed on subsequent occasions and used or extended.

10.3.4 Media Language

The Media Language (ML) (Parrott and Ward, 1993) constructed with the Eiffel programming language was the second step in the evolution of our information modelling tools. Some components from the GPE prototype were reused in Media

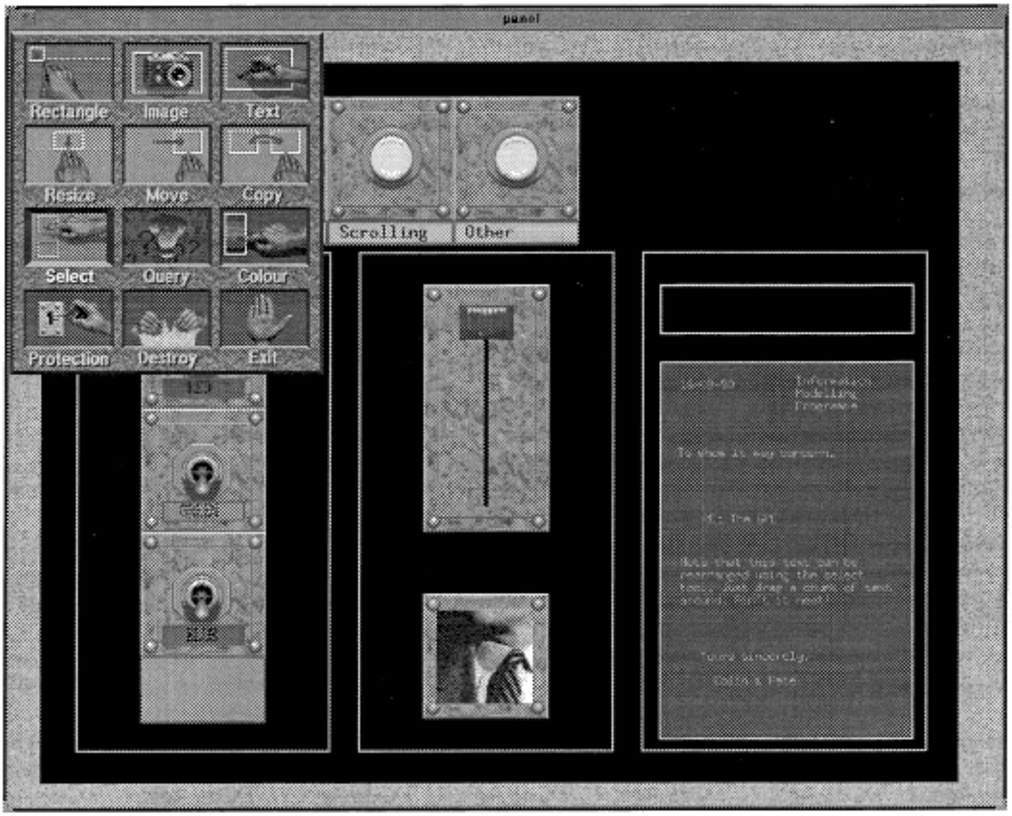

Figure 10.9 GPE toolkit.

Language. ML provides a means to organize and present information available for interaction in the form of chunks, with buttons, labelled graphs (e.g. networks) and selectable text (hypertext). Chunks are fixed-canvass presentation–interaction frames with include text with selectable text ('hypertext'), pictures with animation, graphical networks and buttons. Extending the X11 display capabilities of the GPE for text and pictures, ML includes additional facilities such as animation support and image file importation.

Using a simple English-like scripting language, ML enables authors to construct high-quality hand-crafted interactive browsable presentations, using imported content in standard format generated in outside packages, e.g. ASCII and pcx files from word-processing and graphics tools.

A number of issues and design principles were highlighted in a number of case studies in which ML has been tested and evaluated. When applications grow beyond a small to medium size, then problems of scale and complexity (including the use of hypertext-type links) make keeping track of the content and its structure an issue and the importance of constructing an information model as a framework is key. The performance of larger-scale applications when requested by multiple users, e.g. on institutional networks, necessitated in our view a different strategy for development and distribution. We believed that a level of automation in the construction of

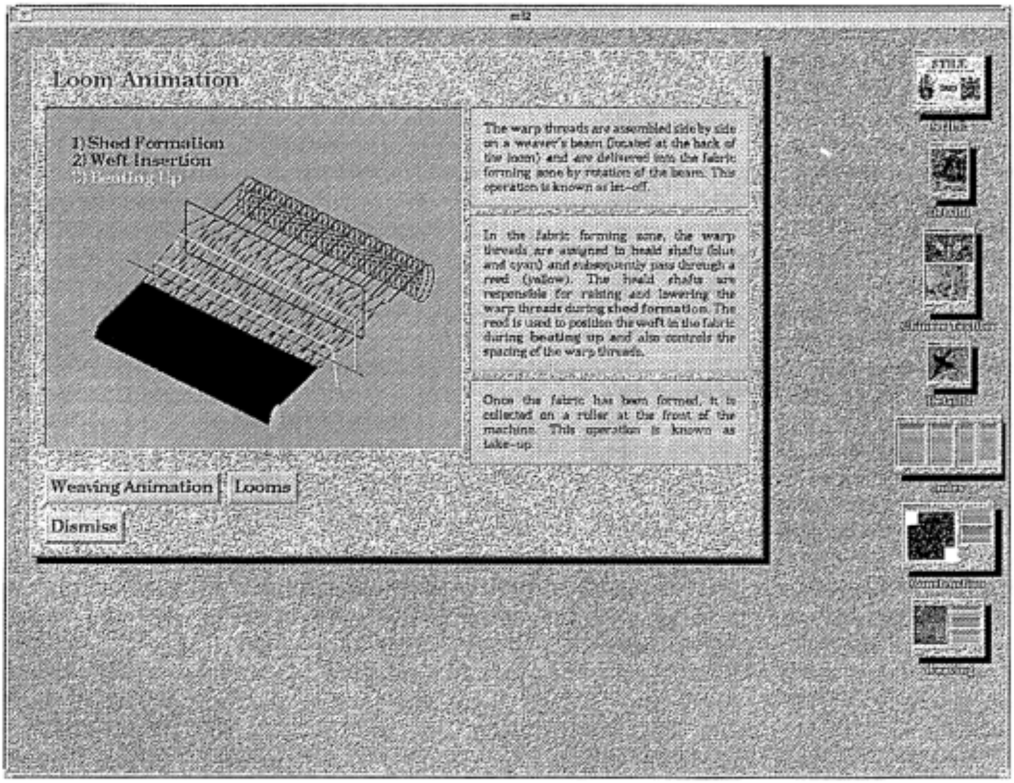

Figure 10.10 A screen from supporting textiles interactive learning environment (STILE), one of the ML demonstrators. Loom animation.

presentation–interaction frameworks and the organization of content would be more appropriate with 'authoring' separated into a number of tasks. These include the specification and supply of paper-based content as domain materials, to be digitized and imported into a framework; the editing and mark-up of content for presentation and interaction; and the management of access permission and distribution with monitoring to users on the network.

When applications grow beyond a small to medium size, then problems of scale and complexity (with the use of hypertext-type links) make keeping track of the content and its structure an issue and the importance of constructing an information model as a framework is key. We concluded that within the context of the development of courseware by teachers, the realities were that while some teachers are very keen and well able to author computer-based applications, the majority of staff have neither the time nor the skills to develop such materials in a sufficiently sophisticated or cost-effective fashion.

10.4 GARDEN

A new prototype tool, General Application Realisation and Development Environment (GARDEN) was developed to address these issues (Ward *et al.*, 1993). It re-used some components from ML (e.g. X11 components), and in order to provide a better distribution model, some useful features of the UNIX operating system were encapsulated (Ward, 1994a; Ward, in preparation).

GARDEN provides a flexible, expandable, enhanceable and distributable electronic book with a number of very useful features. It features an advanced graphical user interface capable of adaptation to practically any display resolution and size (with display support for 256 colours), enabling a wide range of machines to act as delivery platforms. It provides application developers with an effective mechanism for organizing large numbers of text and image files into high-quality interactive applications. It provides multiple users with precisely controlled and monitored access to large-scale textual and pictorial information resources.

The framework for an application can be constructed by information designers from a resource of templates and re-usable features. For example, icons in menus are a subtype of a class: Selectable. Icons, e.g. menu items, can be defined and included in the interface of an application – and they inherit a set of behaviour from the Selectable class, e.g. event handling and four phases of visual feedback in response to user selection. Icons can be of any shape or size and are simply image files supplied by an author to the selectable icon object for display and interaction. This makes the configuration of the user interface very flexible, so that 'menu buttons' can be bananas, fish, or practically anything.

Content can be organized by an application developer through nested menus. The application has a resource model within a directory tree structure based on UNIX files – with content as leaves. Editors can work with authors and originators of materials to ensure content location and mark-up for presentation. System administrators are provided with a flexible network distribution model (taking advantage of NFS-network file services capable of linking different machines providing 'transparent' access to files wherever held on the network), security mechanisms, and time-stamped logging for all user actions and a flexible network distribution model, enabling precisely controlled and monitored access to large-scale textual and pictorial information resources and multiple applications.

One of the first GARDEN prototype applications was delivered to the new Leeds University Environment Centre as the Environment Foundations Course (EFC) in October 1993, and has been used by their first intake of students (Figure 10.11). A subsequent prototype was developed for the University Library, to facilitate communication between librarians and their clients (Figure 10.12). The first prototype supports some of the special needs of educational and training applications. By means of simple control files, the editor or administrator can define prerequisites displayed to the user enabling specific orders of interaction with materials. We are hoping to apply some of our research ideas in the area of instructional technology in future implementations.

10.5 Why SPARC/UNIX/X11?

10.5.1 More powerful computing

Powerful and sophisticated computing technology is required for large-scale, multi-user, multi-process information systems. Distributed digital multimedia documents will

Figure 10.11 A screen from the object base for the organization of the environment – environment foundations course (EFC), the first case study for GARDEN.

be a basic feature of many of these. The multiprocessing, multitasking and support for networking provided by UNIX and the RISC machine are becoming integrated into a new generation of technology and tools, e.g. Windows NT, 'Chicago'/Windows 95, PowerPC and 'Cairo'.

10.5.2 Open system/client–server

The 'client–server' architecture provided by work stations running the UNIX operating system is a type of approach which we have adopted so far to the organization and delivery of multimedia applications – the storage and distribution of large amounts of data, and the provision of services (such as word processing, graphics processing, desktop utilities, and database tools). This is a network enterprise model of computing involving the development of communication and collaboration between clients and servers and a community of users on a variety of terminals. It is a development beyond the mainframe with its 'dumb' terminals and the stand-alone PC. In this model, user access is provided through an interface where the system is at a terminal (end-user seat) through which requests for services, applications and files can be connected with server

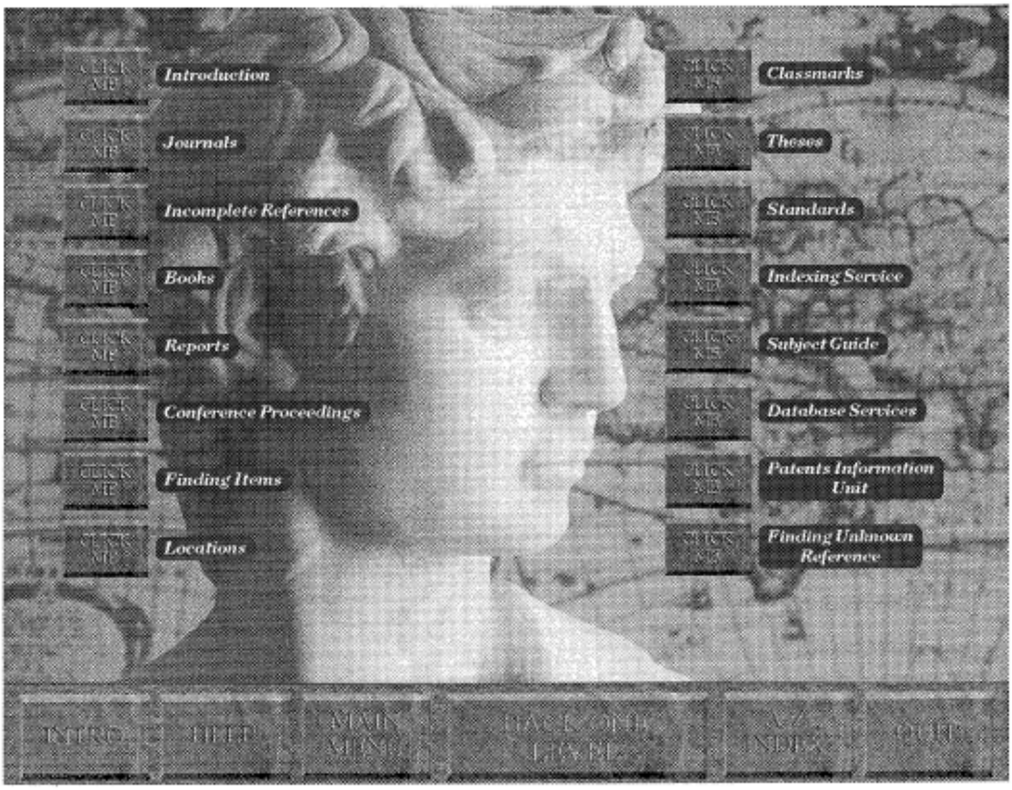

Figure 10.12 A screen from the 'Library Access' project, a second case study for GARDEN.

machines. In GARDEN, advantage is taken of the 'virtual memory' facilities offered by the Sparc machine and UNIX operating system, so that the provision of login to an application and application content on demand is facilitated and the end user experiences good response times and performance.

10.5.3 Portability

Portability has been a principle underpinning the technical approach. UNIX is an operating system which runs on a number of machines including the X86 on PCs; X11 windows provides a machine-independent mechanism for portable user interfaces; and object-oriented languages provide for construction of class libraries of generic and re-usable features which are devoid of implementation detail and principle portable to a variety of platforms by simple extension.

Consistent with a strategy to retain portability and distributability with high performance, we have restricted the multimedia applications to text, graphics and photorealistic pictures. We have left out dynamic data types such as video in the implementation of prototypes until recently because of (apart from cost) the bottlenecks in distribution and the reliance upon local, proprietary hardware. The sophisticated technologies incorporating standards for dealing with real-time data types such as sound and video – are now becoming available.

10.5.4 Distributed and multi-user

Distribution with efficiency and control is what end users want. They want it here and they want it now. The stand-alone solution has given way to the new paradigm of multiple users on the network wanting simultaneous and customized access.

10.5.5 Scalable

In the real world, information systems evolve in scale, scope and complexity: they just get bigger and bigger. New mechanisms for dealing with this are called for.

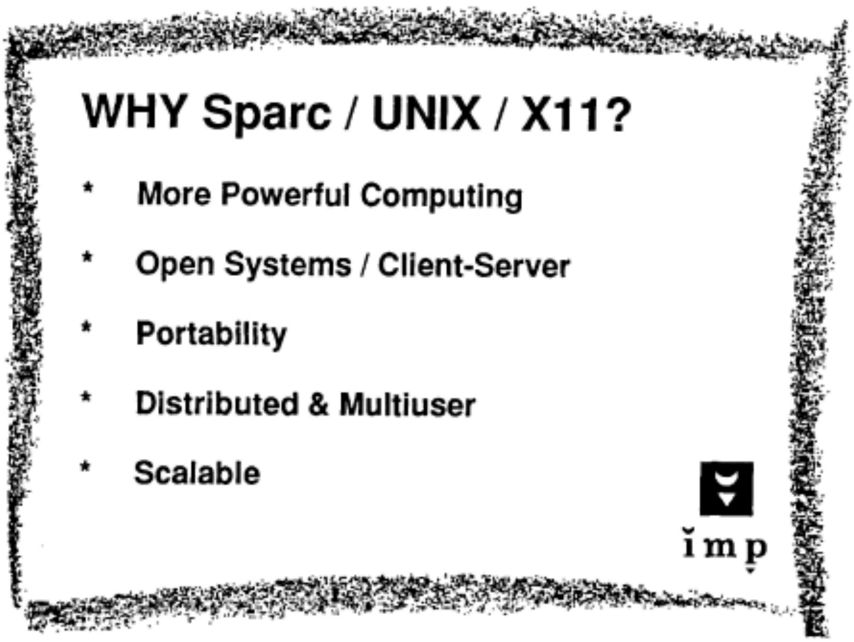

Figure 10.13 Advantage of SPARC/INIX/X11.

10.6 Why Eiffel and OOT?

The possibilities offered by object-oriented technology (OOT) – including factored modular design and reusability of components – are tempting. In an object-oriented approach to multimedia system implementation, we have explored the possibility for reusability of generic components. This is consistent with the need to design and implement generic functionality, e.g. linking the operating system services, the imaging model and the basic features of the user interface, with portability and performance.

Eiffel is a small and powerful object-oriented programming language for both formal specification and implementation and can be especially valuable in evolutionary and expanding systems involving different programmers and software development teams (Meyer, 1992). In our programme of applied research into 'interactive multimedia mechanisms', Eiffel has proved an effective productivity tool in the rapid prototyping and the development of general-purpose and 'reusable' components (including a set of X11 and UNIX classes) and we have demonstrated that working systems can be developed with it (Howard, 1994).

The object-oriented paradigm and object-oriented tools have been found to be a very useful and effective way of developing working models – providing a bridge between the formalism of the machine and the abstraction and description of the real world. This provides a new means to design and implement applications (and information systems) in ways tenable by end-users and which provide, through the agency of object-oriented languages, a direct mapping to the machine.

10.6.1 Generic Components

This has been with a longer-term view to the construction of application and domain objects which are portable and distributable and which can be compiled and delivered on any machine.

10.6.2 Flexible and extensible models

Flexible and extensible models can be reconfigured and extended to deal with varying and evolving demands.

10.6.3 New way of thinking: abstraction, analysis, design, implementation and test

The notion of the distributable, flexible, 'virtual document' requires new mindsets and paradigm shifts. Better tools, better access; simpler and more generic tools which are fun to use; enabling creativity, productivity and communication. Authoring, editing, publishing, displaying, printing, storing, retrieving, repurposing. Processes of document modelling, of information modelling, involving people and machines simply complicates matters. Scale, scope and complexity require new strategies and new components.

Object orientation provides a way to express reality in a series of linked models – from abstraction to formality from real world to the machine and to the postscript file and the printed page or display screen.

From one viewpoint, the electronic document can be regarded as a generic class of thing – with a variety of subclasses or types, e.g. document as applied to manuscript for a book, document as applied to an item of learning material, or document as applied to a patient health-care record.

In the educational arena, supporting pedagogical interactivity involves modelling the processes teachers engage in and linking them to data structures and the materials to be delivered to the learner. In an object-oriented approach, this might involve the provision of an 'object server' for digital documents with general-purpose facilities for the organization and customization of content into various hypermedia structures. Integrated with the document object server and available as a service might be 'intelligent services', e.g. educational advice.

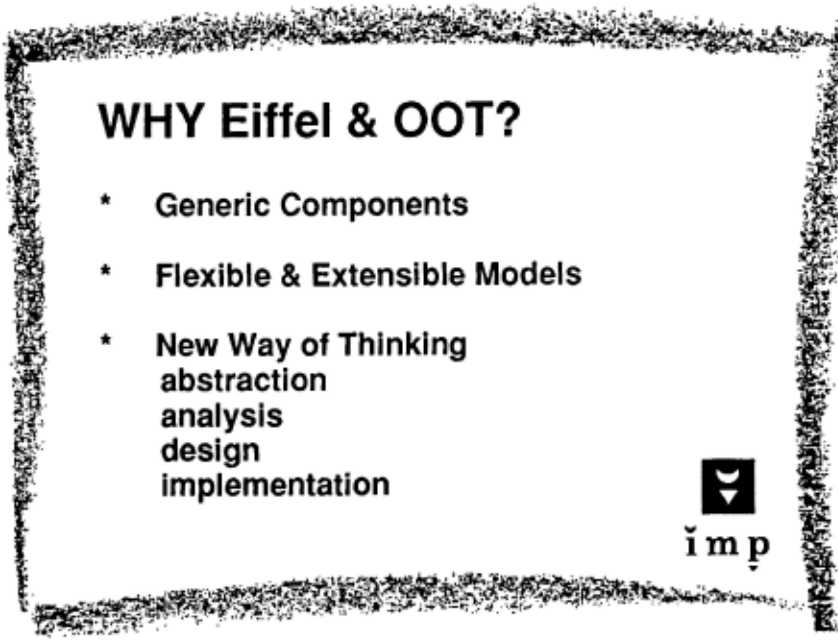

Figure 10.14 Advantages of Eiffel and OOT.

What is the role of objects in multimedia and the electronic document, e.g. in user interaction, interface construction and database retrieval? Can a useful bridge between the developers of applications and the end users be constructed with the object oriented paradigm to add real value to the next generation of solutions? How could object-oriented technology help authors or end users of multimedia documents or applications?

10.7 The 'Text' the 'Hypermedia'?

The classical text as a paper-based artefact is giving way to the new age of the electronic document. Techniques of hypertext and hypermedia offer a means to structure information and knowledge by drawing upon patterns of linkage. Interactive graphical visualizations of information and knowledge domains can provide for flexible ways of exploring a variety of relationship types. There are various possibilities for structured browsing, based on networks analysis and navigation, with quick retrieval of key materials from nodes.

There are two contrasting data models for hypertext/hypermedia – the 'fixed-sized canvas' (as in Hypercard and KMS (Askyn *et al.*, 1988) (to which Media Language chunks correspond)), and 'arbitrary length documents' (as in Augment, Intermedia, Notecards, and Neptune (Englebart, 1984) (to which GARDEN 'Pages' correspond)). In order to contain all the rich possibilities in hypermedia systems, and to relate different interpretations of hypertext, composite structures and a variety of link types are being defined, e.g. the abstraction 'component' has been nominated as a neutral term to encapsulate the nodes and links of classical hypertext (Gronbaek *et al.*, 1994).

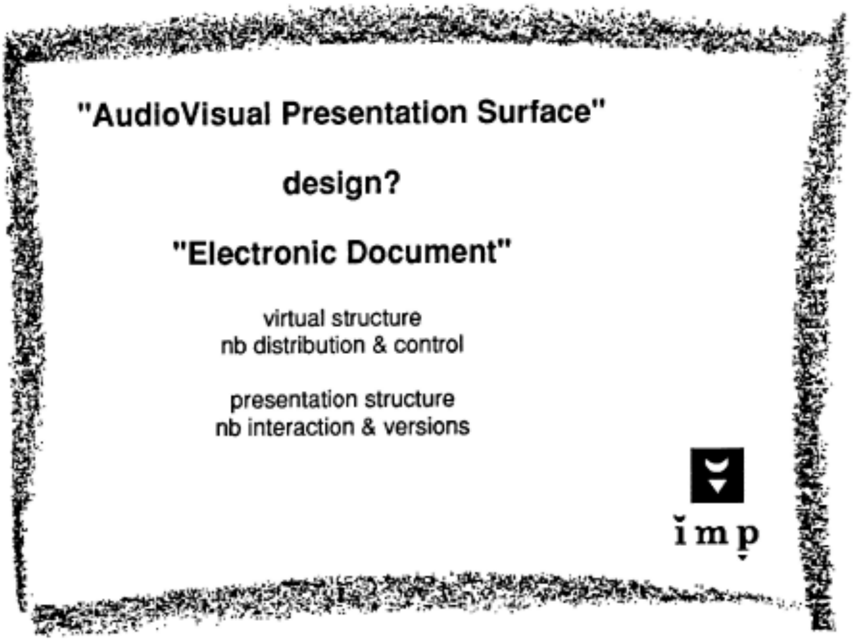

Figure 10.15 The electronic document.

Hypermedia systems are inherently distributed, large-scale and multi-user. It has been clear for some time that new approaches to the design and engineering of hypermedia systems are called for (Ward, 1990; Halasz, 1988). Hypermedia applications have much in common with electronic documents and key implementation issues are generic to both. 'Hypermedia-in-the-large' systems should support: (1) an open philosophy; (2) the integration of tasks as well as information (interapplication linking); (3) collaborative applications; (4) heterogeneous environments; (5) across network linking; (6) versioning of data; (7) public and private links; and (8) access control (*Communications of the ACM*, 1994). Object-oriented techniques are being increasingly applied to the design of the new generation of hypermedia systems – towards resolving ambiguities of representation and to the complexities of relationships.

10.8 Conclusions

Our approach has been to develop working prototypes (demonstrating concepts and mechanisms) providing for the organization of information structures by 'authors', and their delivery through a high-quality graphical interface providing simple access to readers. In our investigation of general-purpose mechanisms for information modelling and application building, we wanted to involve end users in the development process and to explore a variety of subject matter domains, including the humanities as well as science, engineering, biology and medicine.

Our pragmatics of rapid prototyping, cf. construction ultimate solutions, is the development of working models sooner rather than later. Our technical strategy is portability – open, not hardwired to a particular box. Our game plan has been to involve a variety of users and tasks in search of the general-purpose solution. Distribution on a network to multiple users was a basic functional aim. The UNIX operating system, the superior processors in work stations, and newly emerging object-oriented programming languages, offered a development route providing a necessary level of sophistication.

Rapid prototyping with real users is tough work. The problems begin just beyond the first working demonstrator of concept, design, look and feel. Some end users are unaware and ill-informed while others have a little knowledge and high expectations. Defining a specification for an application is a significant and continuous task. Each working prototype can inform a better specification and a better working model. One must avoid misunderstanding and intermediate prototypes being mistaken for final solutions. End users (requesting application development) typically seriously underestimate the resources and time required to meet their demands, and support their immediate and longer-term needs. Most end users as clients for custom applications would be reluctant to concede that a resource equivalent to the making of a 50-min television documentary is probably required (if only). Satisfying all user requirements for multimedia, interactivity and easy access with high performance is a tall order; building working protoypes in short time frames is risky: people are never satisfied. Structured, this can be turned into a mechanism for incremental development. End users cannot be expected to understand how the engineering process and the purpose of prototyping applies to application and software development without explanation.

10.8.1 Electronic document

Paper is a tactile, traditional and personalized artefact and the aesthetic dimension in handling text and other printed media cannot be ignored. Electronic documents will require special qualities in terms of their content and their presentation; beyond the paradigm of the book and reading, the electronic document will have to support a variety of interactivity.

A new arena of electronic publishing and distributed 'information product' is providing a melting pot for the technologies of electronic text, multimedia and the 'hypermedia document'. A new generation of tools and interfaces will be evolved in the next few years, providing a variety of access and control of digital multimedia information and deliverable on alternative vehicles including the CD-ROM and the network. The printed page and the screen display (or audiovisual presentation–interaction surface) present different design challenges and can be regarded as customized 'snapshots'. In order to cater for both screen-displayed documents with facilities for user interaction and for the delivery of the printed document, designers are now concerned with the virtual document and a number of emerging standards for data description and distribution (Ward, 1994b). It will be interesting to see how the rather disparate research areas of electronic text and hypertext, computer graphics and visualization, HCI, and multimedia come closer together in contributing technical components of a more general-purpose solution.

In a future world described in the Turing option 'with eternitree you can print the book you want, slip the sheet into a spring binder and sit in the sun while you read'.

10.8.2 Lessons applicable to electronic publishing?

More case studies (especially in electronic publishing) are needed as guides, and rapid prototyping over short time frames and the incremental scaling and enhancement of models is a way to inform this process. Practical experiences with the new and developing object-oriented application development environments – especially in the arena of larger scale and distributed applications – are of considerable interest to organizations such as publishers looking for new mechanisms for productivity.

Publishers will need new tools and mechanisms to enable them to work with authors of texts and to give them a necessary measure of control over a radically new business opportunity. CD-ROM suggests a convenient and cost-effective way of delivering large amounts of data and electronic documents. However, multimedia applications can also be shipped out continuously on-line to local and wide area networks. Increments to an evolving application or hypermedia document can be made either way and, for example through electronic mail, materials can be originated and distributed to editors for further organization. An application or document will require a superstructure or framework (including an information model) which is additional to the information itself, any description of its formatting for the purpose of printing or display, and independent of the means of implementation and any particular platform.

10.9 The Applied Research : Future Directions

Rather than attempting to meet requirements with single products or proprietary systems, a way forward is the identification of 'best-breed-components' and then organizing them into working models matched to user requirements, employing standards for interoperability and distribution. There is increasing interest in the real potential of object-oriented technology in the provision of a new generation of working solutions, e.g. in interface construction, user interaction, database retrieval and the distribution of data. OOT has the potential to contain the scale and complexities of the real world and the next five years will see a new generation of working models which are flexible, and which can be incrementally extended and enhanced. Although around for some years in the informatics community, the object-oriented paradigm is still to the majority of potential beneficiaries a new way of thinking which has a certain immediate appeal. The 'NextStep' interface and application construction toolkit is an example of a new generation of OOT which has had a real appeal for end users in important application areas such as the financial market, providing a means for end users to have hands-on modelling of their tasks.

Object-orientation is an approach to the analysis and description of information systems and the prototyping of applications with general-purpose components. It is important to establish a common model for communication between designers, engineers and end users. Will the representation (design : system model) mean anything to the user; is it accessible? It matters.

The original idea to develop *de novo* object-oriented components of an application development framework was ambitious and risky. However, we have been able to demonstrate that object-oriented technology provides a mechanism to deliver working prototypes. The advantages of encapsulation, inheritance, polymorphism and propagation provided by OOT have been proved to facilitate extension and customization to meet more specific and individual requirements in an evolutionary series of multimedia tools and components.

These prototypes have not been the perfect, ideal or complete solution, but provide a logical step along a technical development and are potentially useful tools for the investigation of better prototypes.

New interdisciplinary viewpoints and skills are needed. The disciplines of electronic engineering, computing science, cognitive science, information design and literary expression all have contributions which must be increasingly integrated into better designs and the evolution of the next generation of information systems.

Rather than seeking to acquire or develop the perfect application authoring (development and delivery) tool, a future strategy might be the identification and integration of a variety of best-of-breed technologies and components – each providing a key functional feature required, with interoperability among such components as part of a greater information system framework.

The aim of an information system should be 'enabling' rather than 'allowing'. The interface must be attractive, engaging, easy to use and take into account the need for flexible access to information resources which can be configured and re-organized, customized and reused in any number of ways, providing access to a variety of users. It should be portable across a variety of machines; it must be customizable to some extent; it must have high performance and accommodate future trends for large-scale multi-user distributed multimedia systems. There is a large variety of potential users for such systems who will want to browse digital multimedia information, index and organize it into varieties of information and knowledge structures including links, and thereafter store, retrieve and distribute it in effective and efficient way. A key requirement will be to enable information, e.g. as documents, to be moved around in a measured, organized and controlled fashion.

The electronic document can be envisaged as a virtual, dynamic and distributable artefact. Such documents will be accessed by multiple users within cooperative working environments across many platforms with interdocument and interapplication communication. There are no doubt different horses for different courses – e.g. health-care/medical information systems have special requirements for access and interactivity – such as the distributed electronic health record – which are in contrast to hypermedia texts promoting the study of narrative in the field of literary studies.

New mechanisms are being developed for controlled distribution and transaction management, for the configuration of flexible user interaction, and for the management of versions. Looking beyond the first wave World Wide Web and interfaces such as Mosaic, we are currently developing components attempting to lever and re-use components from the earlier prototypes – Media Language and GARDEN.

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