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Book Chapter

"SMILE - an approach to the design and development of information modelling tools for the organisation, management, distribution and delivery of digital multimedia applications"

[based upon the Presentation - "Supporting Multimedia Interactive Learning Environments - an approach to the Design, Development and Delivery of Information Modelling Tools and Applications" at BCS CONFERENCE LEEDS Dec 6-8 1994]

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Abstract
Electronic publishing and the controlled distribution of digital multimedia materials on multiuser networks share many common features, issues and requirements. A user-centred approach to applied prototyping and an evolutionary development of tools and generic information modelling components for the organisation and distribution of digital multimedia using object-oriented techniques is described. Mechanisms for supporting multimedia interactive learning environments include the delivery of "electronic documents" to multiple users on institutional networks. Practical experience in developing working models of applications with end-users in the educational domain is illustrated with a variety of case studies; some lessons learnt and methodological pointers are summarised. The paper is structured around the OHP's used in the conference presentation.

SMILE
The 'SMILE' Project (Supporting Multimedia Interactive Learning Environments) is part of a programme of applied research and development being conducted by the IMP Group at the University of Leeds into a new generation information modelling tools (ref #1: Ward 1994).

The programme of work was originally born out of a sense of frustration and alienation with computers and with their operators. The model represented by them was not attractive and not immediately engaging. It was clear that the computer was capable in principle of processing data - including graphics, text, pictures and sound - and enabling information modelling in multiple and flexible ways. This stimulated an idea of creating new means of access to information - attractive, interactive and engaging - and exploring new mechanisms and creating new artefacts for supporting people within new interactive computer-based environments.

The basic aim of the work is the analysis, design and prototyping of general purpose mechanisms for the modelling, organisation, distribution and management of multimedia materials. Providing better access. This is extended to application in an educational environment where positive interactivity and enjoyment can add real value to the learning experience. Learning is something we must all do and computers have presented themselves as candidates for a new means of 'open', 'distance', 'just-in-time' and 'life-long' learning. Pedagogical interactivity - between the teacher and the pupil - is a type of interaction which involves a number of special processes and features. Supporting multimedia interactive learning environments includes the delivery of "electronic documents' to multiple users on an institutional network. The 'SMILE' Project is focused on modelling and delivering this variety of interactivity as a functional enhancement (module) of a general purpose (modular) system. The idea of the educational project has been to implement an "educational advisor" (ref #4: Arshad and Kelleher 1993). Such an entity has been envisaged as a component of a modular system providing a number of services - an "intelligent agent" accessible as an interface artefact (ref #2: Ward 1990; ref #3: Ward and Arshad 1992).

[SMILE pic smileys from IMP profile]

Design, Development & Delivery of Information Modelling Tools
A Challenge - to enable new means of information modelling & 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 organisation. 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.

There are a number of tools offering a variety of means for the representation and communication of information and ideas. As well as presentation, there is the dimension of "interactivity" to account for - the provision of flexible means of access and mechanisms for accessing information varying from brief, factual and down-right fast, to lengthy, complex and exploratory.

Currently there is growing interest in tools for authoring and managing electronic documents: and the creation of a new means of access for readers and writers. 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 evolving information models) are called for.

[OHP "Design, Development & Delivery of Information Modelling Tools]

A Challenge - to enable new means of information modelling & communication, employing the "best-of-breed" from emerging technologies"

The model : PEOPLE, INFORMATION, PROCESSES, MACHINES and ???

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 (i) provide access, (ii) to a varied population of users, who (iii) want to model, and (iv) to distribute information in, (v) all its richness, (vi) in order to communicate, (vii) abstract ideas, (viii) discrete knowledge, or (ix) specific information. The 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 organisation and distribution of digital media materials, and the design of new communication structures eg hypermedia documents, graphical user interfaces, browsers and intelligent filters.

[OHP "INFORMATION, PROCESSES, MACHINES?"]

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 eg in the domains of education or publishing, then end-users will include teachers and authors/experts/editors of domain materials - communicators, experts in subject matter and material domain modellers.

[OHP "PEOPLE

*** "End-Users"**

*** Designers and Developers**

*** Administrators and Editors"]**

Information
The information component of an information system will include a variety of digital (data) media types - static: text, graphics & pictures and dynamic: animation, video 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 synchronisation 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. The 'document' is a conventional paradigm for communication. Systems which provide simple modelling tools and support for the realisation and distribution of a variety of information structures.

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".

[OHP
"INFORMATION

*** 'Multimedia' data types: static and dynamic**

*** text, symbols, pictures, sound**

*** Information Structures"]**

Processes
The processes component of an information system will include at a low level: methods acting on data and events, and at all levels: communication (eg of data and 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 eg 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 formalise 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 realisation, organisation and dissemination of electronic documents is a complex set of tasks and involves a number and variety of processes.

[OHP
"PROCESSES

*** Creativity**

*** Communication**

*** Electronic Publishing"]**

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 92], 'C' and the object-oriented programming language Eiffel [Meyer 88,92].

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.

[OHP
"MACHINES

***Sun Microsystem SPARC**

***UNIX/X11**

***'C'**

*** Eiffel OOPL"]**

HOW?

Rapid prototyping of Information Modelling Tools & 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 committment of the telecommunications industries to the evolution of the next generation of "superhighways", "intelligent terminals" and information product and services. Main threads of commercial R&D 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. Modelling a framework of components for facilitating the organisation, distribution and management of multimedia information resources. Rapid prototyping means short-time scales between working models with small but significant increments.

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 91, 93, 94].

Our aims have included the development of high performance graphical user interfaces (GUIs), and mechanisms for the support of the acquisition, organisation 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.

The "open systems" approach is consistent with the realities of networks of heterogenous 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.

[OHP
"HOW?

Rapid prototying of Information Modelling Tools & Components

Creating a prototype - pragmatics of applied research involving end-users

Creating a prototype - object-oriented technology and re-usable components"]

Result
A number of working prototypes and tools have been evolved, including a set of class libraries and three higher level application organisation and delivery tools : Graphical Programming Environment (GPE), Media Language (ML) and GARDEN [Parrott 91, 93; Ward 94]. This has been towards a means to import and then to organise 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 'GPE' (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 91].

[***Illustration #1 GPE Toolkit (including panels and letter)]***

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 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.

[OHP
"RESULT

Media Language

GARDEN

Application - Case Studies"]

Media Language
The 'Media Language' ('ML') [Parrott 93] 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 Language'. 'ML' provides a means to organise 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.

***[Illustration #2** Shows a screen from STILE (supporting textiles interactive learning environments), one of the 'Media Language' demonstrators. Loom animation]*

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 presentation-interaction frameworks and the organisation 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 digitised 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.

GARDEN

A new prototype tool 'GARDEN' (General Application Realisation and Development Environment) was developed to address these issues [Ward 93]. 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 1994; 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 organising 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 eg 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 organised 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.

[Illustration #3 *Shows a screen from the 'OBOE-EFC' (object base for the organisation of the environment - environment foundations course) the first case study for GARDEN.]*

One of the first GARDEN prototype applications was delivered to the new Leeds University Environment Centre as the the 'EFC' (environment foundations course) in October 1993, and has been used by their first intake of students. A subsequent prototype was developed for the University Library, to facilitate communication between librarians and their clients. 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.

[Illustration #4 *Shows a screen from the 'Library Access' Project, a second case study for GARDEN.]*

Why SPARC/UNIX/X11?

More Powerful computing

Powerful and sophisticated computing technology is required for large-scale, multiuser, multiprocess information systems. Distributed digital multimedia documents will 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'.

Open System/Client-Server

The "client-server" architecture provided by workstations running the UNIX operating system is a type of approach which we have adopted so far to the organisation 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 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.

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 PC's; X11 windows provides a machine-independent mechanism for portable user interfaces; and object-orientated languages provide for construction of Class Libraries of generic and re-usable features which are in 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, proprietory hardware. The sophisticated technologies incorporating standards for dealing with real time data types such as sound and video - are now becoming available.

Distributed & Multiuser
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 customised access.

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.

[OHP
"Why SPARC/UNIX/X11?

***More Powerful computing**

***Open System/Client-Server**

***Portability**

***Distributed & Multiuser**

***Scalable"]**

Why Eiffel & OOT?
The possibilities offered by object-oriented technology - 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 re-usability 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.

The 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. 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 're-usable'

components (including a set of X11 and UNIX classes) and we have demonstrated that working systems can be developed with it [Howard 94].

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.

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.

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

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, re-purposing. 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 eg document as applied to manuscript for a book, document as applied to an item of learning material, or document as applied to a patient healthcare 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 organisation and customisation 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.

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 OOP 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?

[OHP
"Why Eiffel & OOT?

***Generic Components**

***Flexible & Extensible Models**

***New Way of Thinking**
abstraction
analysis
design
implementation
test"]

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 visualisations 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 canvass' (as in Hypercard and KMS [Askyn 88] (to which Media Language 'Chunks' correspond), and 'arbitrary length documents' (as in Augment, Intermedia, Notecards, and Neptune [Englebart 84] (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 eg. the abstraction 'component' has been nominated as a neutral term to encapsulate the nodes and links of classical hypertext [Gronbaek 94].

Hypermedia systems are inherently distributed, large-scale and multiuser. It has been clear for some time that new approaches to the design and engineering of hypermedia systems are called [Ward 90; 7 key steps]. Hypermedia applications have much in common with "electronic documents" and key implementation issues are generic to both. "Hypermedia-in-the-large" systems should support: (i) an open philosophy, (ii) the integration of tasks as well as information (inter application linking), (iii) collaborative applications, (iv) heterogeneous environments, (v) across network linking, (vi) versioning of data, (vii) public and private links, and (viii) access control {ACM Special Issue Hypermedia 94]. 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.

[OHP

"The "Hypermedia"?

The "Text"?

communication"]

Conclusions
Our approach has been to develop working prototypes (demonstrating concepts and mechanisms) providing for the organisation 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 workstations, 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 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 minute 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 protoyping applies to application and software development without explanation.

"Electronic Document"
Paper is a tactile, traditional and personalised 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 customised '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 (ref: IMI Ward 94]. It will be interesting to see how the rather disparate research areas of electronic text and hypertext, computer graphics and visualisation, 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".

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 organisations 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. CDROM 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 organisation. 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.

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 organising 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 (OOT) 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 5 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 customisation 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 a logical step along a technical development and a 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-organised, customised and re-used in any number of ways, providing access to a variety of users. It should be portable across a variety of machines; it must be customisable to some extent; it must be high performance and accommodate future trends for large-scale multiuser distributed multimedia systems. There is a large variety of potential users for such systems who will want to browse digital multimedia information, index and organise it into varieties of information and knowledge structures 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 and in a measured, organised 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 inter document and inter application communication. There are no doubt different horses for different courses - e.g. healthcare/medical information systems have special requirements for access and interactivity e.g. 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.

A principal aim has always been a high quality, visually interesting, interactive and cognitively satisfying graphical user interface – a combination of the fewest useful icon/buttons and information-rich information/knowledge models : employing strategies for interaction, good graphics and software engineering from the domain of games programming. Applied to learning – where a dimension of challenge and fun and where computer-based mechanisms and educational materials should be properly viewed as part of interactive learning environments.

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