A Model Design for Computer based Cognition Support Systems

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1.0 Introduction

Different life forms have been gifted with a different mix of powers to sense the physical world and interact amongst themselves. Intra-species Interaction among all life forms is psycho-physiologically essential and natural. Most primitive forms like amoeba can sense the environment only by physical touch, whereas advanced life forms have more senses. Man has been gifted with five senses to register some characteristics of the physical world. Though other animals specially mammals and birds also have five senses, the resolution, accuracy , range and bandwidth of each sense differs in different species. Because of the great gift of an advanced brain to man, his psychological needs for interaction and communication far exceed the physiological reasons. A very significant amount of human effort is targeted towards pursuit of knowledge. Pedagogical communication is the most important form of formal communication. Fast growing corpus of human knowledge offers interesting communication design challenges to academicians and designers.

While animals can communicate with the limited sounds, rich spoken languages are nature's unique gift to man to facilitate communication. Since the early days, man has been generally communicating through oral and/or visual expressions. *Natya Sastra*, the ancient Indian text on performing arts, had limited the sensory scope of artistic expressions to eye and ear only. Empowered by his unique ability to make tools, it was most natural for man to develop tools to record, store, transmit, render and disseminate these expressions. These tools allowed him to communicate across the barriers of physical space and physical time. Though research to develop the tools to support other senses is also in progress, the tools for audio/visual support are sufficiently mature and continue to draw the attention of the largest number of developers for further improvements. The word "Multimedia" has become popular in the context of concurrent presentation of multiple audio/visual elements to formulate and communicate richer expressions.

Communication "*Content*" may include data, information, creative expressions or analytical interpretations in different media. *Data* refers to factual representation of reality, usually it is captured mechanically and may not be much useful in its raw form. *Information* is mechanically filtered out of data to provide a focussed answer

to a specific query. *Analytical interpretations* result out of scientific analysis of reality. Some of these discoveries can be proved to be factually correct and may get accepted as data. *Creative expressions* reveal intellectual and creative faculties of human mind, and may be partially or fully inspired from the reality. They are highly subjective and allow a non-disturbing co-existence of contradictions. The notion of consistency and completeness can not be rigidly applied to these expressions. *Designs* are a form of creative expressions with more or absolute emphasis on consistency and completeness, and are grounded in deep analytical understanding of the reality. Analytical interpretations and creative expressions result out of human intelligence and can not be mechanically inferred from the data and/or information. Researchers of Cognitive Science and Artificial Intelligence are trying to model and partially simulate these human capabilities.

Communication technology has been history's driving force[ ][i]. Man took almost 50,000 years to start the development of scripts in ca. 3500 BC. Well structured scripts based on proper alphabets were developed around 1000 BC. Because of the power of the written word, the next significant progression was made in just 2500 years when printing technology became available around 1500 AD. The 19th Century empowered us with machine aided recording and communication of audio/visual details. Electronics started another revolution in the late 19th Century and Human expression could be captured and disseminated electronically. Different technologies were developed for "soft printing" of different kind of expressions. Electronic technology has now reached a maturity level that empowers us to handle different expressions almost in a uniform manner. All these advancements have helped in democratisation of the access to learning material and an increase in the general education levels.

To support human communication , the electronics industry has made significant progress in Telecommunication, Consumer & Entertainment Electronics and Computers. Technology has reached a certain level of maturity in each of these areas. Since the very beginning there have been occasional exchanges among these areas; however, it is only recently that an integrated approach for further development has started. The Publishing industry has undergone a revolution in the last twenty years because of the integration of the Printing Press with Computers. Until recently computers did not support high capacity, portable content storage devices. Because of this limitation, computers could not be used as communication and educational medium. Their usage remained confined to data processing, information systems, physical process modelling and control applications. With the increased processing power and storage capacity, a new communication medium has become available. *Computer based "Interactive Multi-media"* is now facilitating the simulation, extension and integration of various communication technologies to facilitate multi-sensory communication and learning.

Technologies are not mere exterior aids but also interior transformations of consciousness[ ][ii]. The form and the structure of the discourse has been influenced by the affordances of different tools. All communication technologies have their strengths and weaknesses that are gradually realised after some years of initial experimentation with the technology as a communication medium. It took several decades of book printing for a useful and generally acceptable book form to emerge

out of the tradition of costly medieval manuscripts[ ][iii]. For several years, motion picture directors continued to use the new medium as theatre, and it took quite some time for producers to stop using television as glorified radio. Interactive multi-media technology also will soon be able to create a niche place for itself out of the legacy of the earlier media.

Depending upon the level of activity by communicators, communication can be broadly classified into the following categories[ ][iv]:

1. Passive Receiver, Passive Source (for Pass Time, e.g. Exhibition visit)
2. Passive receiver, Active source (for Public Address, Entertainment, Mass Education e.g. Joy rides, Broadcast)
3. Active Receiver, Passive Source (for Search, Learning, Entertainment e.g. Books, Exhibition visit)
4. Active Receiver, Active Source (for Interaction, Exchange, Learning, Game based Entertainment e.g. Class room teaching, Simulator, Real Life, Video games)

Here, the phrase "passive" does not imply completely inactive receiver; it only reflects a relatively lower activity by them. Unlike the audience of an entertainment programme, a learner actively participates in a symmetric duplex communication with the teacher, peers and pedagogical resources. Learner's activity is the most significant contributor towards effective learning. Several tools are available to support these activities and reduce the load on the learner and enhance the learning. Computers have the potential to amplify the extent of this support.

Computers offer interesting novel possibilities of *interactivity* and of *integration* of data, information, analytical interpretations and creative expressions. The issues being addressed by researchers and practitioners engaged in the area of Interactive Multimedia can be broadly abstracted as follows:

1. Recording, Rendering, Transmission, Storage and Retrieval of Multimedia Data, Information, Analytical interpretations & Creative expressions.
2. Synthesis of Multimedia Information, Analytical interpretations & Creative expressions.
3. Analysis of Multimedia Data, Analytical interpretations & Creative expressions.
4. Design and development of Multimedia Communication Systems.

A lot of work has been carried out by computer scientists to address the first two issues and sufficient core technology is already available to the designers and developers of Multimedia Communication Systems. Several techniques have been developed for Text Mining, Speech analysis and Image analysis. Rapid technological advancements are empowering the designers with even better data encoding, retrieval, rendering, synthesis and analysis tools. Technology assisted content analysis in certain domains like art history has not yet been much experimented. Though several groups are developing pedagogical multimedia systems, adequate work has not yet been reported to set the detailed design and process guidelines. Several authors have focussed on different aspects, a detailed design model has not yet been reported. An attempt has been made to propose a detailed design model for pedagogical multimedia systems in this paper.

1.1 Computer based Cognition Support system:

Amongst other social activities, education ranks very high as one of the main beneficiaries of advancements in communication technologies. But unfortunately, it has not been the first to take advantage of some of the key advancements. It is the entertainment industry which has made the largest investments in applying the upcoming communication technologies. Though *cognition* is an internal and subjective process, it gets greatly effected by the way the study material is made available to the learner. Technology, if appropriately applied, can support cognition and enhance the learning. The design requirements of educational software using any of these technologies are not the same as that of an entertainment software. While media experts can exploit the communication technologies for developing entertainment and informative software, the educationists themselves must play the main role in designing and developing the software for pedagogical purposes. While educationists are playing the central role in book publication, they need to closely collaborate with media and technology experts for using other communication technologies. Multidisciplinary nature of developing computer based educational software makes the cost of such a development quite unaffordable by small groups. Interactive multimedia demands specialised technical and design skills, these projects are generally being planned and managed by multi-media experts. Educationists themselves are acting as resource persons with the core responsibilty being with multimedia designers. The success of this technology as an accepted and effective medium of education will ultimately depend upon the level of confidence with which educationists will be able to conceive, plan and manage their projects. It is expected that much of the design effort will be saved with the proposed model and educationists will be able to specify system features more explicitly. With this model, the educationists can take up the core responsibility for content creation and multimedia experts can focus on their task of digital realisation.

Learning as an activity starts with exposure and progresses through pedagogical resources with the help of *cognitive processes* [ ]. Pedagogical resources include *study material* and external as well as internal *cognitive tools*. Study material comprises of multiple forms of primary and secondary *"Content"*. Primary content includes the copies of original object under study and Secondary content is the scholarly discourse/ interpretation/ commentary of the primary. In general, only fortunate few learners have been able to have access to primary content. High duplication costs of the non-textual study material has been a major deterrent against democratised learning. This problem can now be solved by the digital technology because rapidly reducing duplication cost of digital content is media independent. It is now feasible to provide instant access to large amount of duplicated primary content to much larger population in a very cost effective manner. Rapidly decreasing costs of multi-media ready computers will soon take them to almost all middle class families of most of the countries. Educational software will take a major share of computer software on such home computers.

Because of the powerful and fast-growing technological potential and lack of enough maturity in the area, there is a lack of suitable models for applying interactive multimedia technology to develop educational software. As happens with any new

technology, people from varied backgrounds have been trying to develop Computer based educational software with different kinds of approaches. Some use Computer as an extension of Video, some extend the databases to include multimedia objects, while some extend the electronic text to offer a hyper-linked network of visual resources depending on their background primarily being in Video, Information sciences or in Data Engineering. Singularly all these approaches fail to exploit the full potential of the computer as a general purpose Simulator.

Initially new materials and media are generally used as a mere substitute for the existing technologies. However, new technologies create a genuine place and social need for themselves only after novel features offered by them are taken advantage of by the Designers. Computer aided Instruction (CAI), Computer aided Learning (CAL) and Computer based Teaching (CBT) are three popular words amongst educationists. Systems developed under these categories do not offer sufficient study material, and also do not seek to support various cognitive processes. The following Notes are a summary of the author's research towards developing a model design for *Computer based Cognition Support Systems*. It has gradually evolved over the last three years and is a result of the author's involvement in the design of several multimedia projects at IGNCA on a variety of interesting subjects in collaboration with some well known art historians, archaeologists, anthropologists, epigraphists and linguists. It is hoped that the proposed model's applicability is not limited to these domain of Arts only, and it is generic enough to be applied to other disciplines as well. However, the author has not yet had the opportunity to apply the model to other disciplines to confirm the claim.

The recently developed and quickly expanding field of Cognitive psychology throws a very useful light on the learning process. A closer look into the process opens up interesting opportunities to the designers of Interactive Multimedia Educational Software. Learning is multistage process and results into formation of higher level mental constructs known as *Cognitive Maps*. Oriented learner gradually makes a transition from an intelligent but mostly passive receiver to an active information collector and finally to a researcher. Different kind of cognitive activities are performed during different stages. Learning results into mental encoding of knowledge which is internally represented by multidimensional higher level mental constructs known as *Cognitive Maps*. Faithful external representation of these internal cognitive maps results into efficient teaching. A novel generic knowledge representation scheme to externalise the Cognitive Maps has been formulated and applied to all the ongoing projects by our group.

Digital technology is helping us to redefine the notion of the book from a static and linear collection of limited visual content to a dynamic and non-linear corpus of large body of multimedia content. The proposed model has evolved out of the desire to support the learning process at all stages and extend the 'Book' paradigm. Computers ability to store large volumes of instantly available data, to represent any structure or behaviour, and, to integrate multiple elements are three underlying strengths on which this model is based upon. It tries to harness the power of interactive multimedia by offering extensive *study material and pedagogical tools.* Special attention has been paid to enhance the interactivity. Effective mechanisms have been proposed to facilitate uniform and quick exploration, rendering and analysis of large digital corpus

of primary, secondary and tertiary content. In short, the model tries to free the 'Book' from the constraints of the paper. While there is a lot of activity going on in the development of multimedia presentations, this model can be used to develop serious study aids on any subject.

According to Hisenberg, famous physicist of modern times, the synergy between thinkers from seemingly different disciplines has helped in giving major turns to civilisation. Absolutely fresh and new ideas emerge during such multi-disciplinary collaborations. Multimedia development is one such multi-disciplinary activity. Successful educational multimedia projects will emerge as a result of very close collaboration between subject experts, educationists, computer scientists and media designers. This synergy between Computer Science and Humanities is opening up new research methodologies and interdisciplinary research problems for scientists, and as a consequence, is producing far more comfortable, enjoyable and holistic learning for the learners.

If the concerned collaborators have sufficient skills to play more than one of the above mentioned roles, the synergy is going to be even more fruitful. While the collaboration between subject experts, educationists and media designers is an established practice, the involvement of computer scientists becomes essential because of the immature level of so called easy to use multi-media authoring tools and proper design models. As these tools gain the maturity to really harness the actual potential of the underlying technology and some projects set the example by offering powerful content exploration tools, computer scientists' role will become more focused on the development of the development tools rather than the individual multimedia projects. At the moment the responsibility to educate the subject experts and educationists about potential possibilities largely lies with the computer scientists. Soon the subject experts and educationists will start pushing the agenda for the computer science community by demanding more features in such tools. Creative subject experts have played a very significant role towards the development of the proposed model.

An attempt has been made to develop reusable generic design specifications for developing Interactive Multimedia Projects. Some of the proposed features have already been implemented by our group . More features are under development. It is hoped that much of the design activity for individual future projects can be cut short by selecting features out of the proposed set. However, creativity never stops and the model will continue to evolve to reach higher goals. The following text presents achievable generic design goals for serious designers. Issues related to Corpus configuration and Media component selection are discussed in 'section 2'. 'Section 3' briefly introduces the complexities of learning process and provide the theoretical foundation for proposed interactivity features discussed in 'section 4'. Finally, 'section 5' focuses on the Quality related issues.

2.0 Corpus Configuration:

According to Marshall Mcluhan, a well known media scholar of 1960s, a given technological medium itself determines or in large part influences significantly the message that it will convey. The primary tool for communication is the symbol, and man has been termed as a symbol using animal[ ][v]. Computers started as storage, processing and retrieval device for numeric symbols and soon were able to handle textual data. With the help of digitisation devices, Pictures, Audio, Video and other forms of expressions can also now be dealt with, although computers still are most efficient with alphanumeric representation. Digital representations of other expressions don't yet allow a very easily implementable and reliable content based retrieval unless the content is supplemented with textual codification; and also they consume much more storage space per minute of information.

Appropriate data-encoding and compression techniques should be used to digitise the content corpus. With careful planning, either of the following data elements can be stored on one CD-ROM, today's removable data storage medium:

a) More than 2 Lakh pages of the Printed Text or
b) Approximately 15,000 Broadcast quality colour Pictures or
c) Approximately 20 hrs. of Broadcast quality Audio or
d) Approximately 5 hrs. of CD quality Audio or
d) Approximately 75 minutes of Broadcast quality Video

The physical data storage capacity of the upcoming DVD is eight times the capacity of the CD-ROM and the recent trends in multimedia data encoding research promise a much higher density of data per Mega Byte of storage space. Hence, it will soon be possible to store much larger corpus on easily portable disks. The quality of audio-visual elements is also improving because of the increased data density and newer algorithms. Further, the Internet offers the possibility of boundless corpus to be offered to the interested learners.

On an average experienced readers read approximately 20 pages in an hour. Hence, it can be seen that 2 Lakh pages of printed text provide a study material for approximately 10,000 hrs. Surely, except for encyclopaedic systems, this amount of study material is not very desirable to be fitted in one CD-ROM. Hence most of the space is usually allocated for storing other media components, e.g. Pictures, Audio and Video.

Though the educationists have experimented and utilised the upcoming communication technologies, it is interesting to have a look at the media choice pattern of the learners. Books still remain the most popular medium for self learning i.e. *"Swadhyaya"*. Though available for the last few decades at an affordable cost, Video has not become a very popular educational technology for focused learning. The same is the case with the Audio Cassettes. This is not to be confused with aired Audio- Visual programs through radio and television. While these audio-visual programs are very effective for mass education through broadcasting or occasional group viewing , it is the printed word that has remained the primary tool for personal learning. In the Study Rooms of most of the learners, books and photo albums continue to outnumber the audio and video cassettes. Hence in order to make it a really successful pedagogical medium, the interactive multimedia is recommended to

be used as a meta-medium for the development of learning aids based on a design model which is primarily an extension of the book paradigm. In short, it should include the features of currently popular educational technologies and the novel content processing and searching possibilities being offered by the computers.

Many designers coming from a video background tend to use a lot of video in the CD-ROM Multimedia systems and very often come across space limitations. A designer should try to arrive at a proper balance of media components for optimum utilisation of the today's technological possibilities. Properly laid down design objectives help in arriving at right decision. As already stated, video consumes a lot of space and hence it should be used very selectively. Ideally it should be used to demonstrate kinetic action. A well conceived mix of still pictures, music and oral commentary often serve the purpose equally well. However, selective usage of small video clippings greatly enhances the learning possibilities.

The uniformity of underlying digital encoding principle offers the unique possibility to mix and integrate different media components at multiple levels. Respective strengths of carefully selected primary medium need to be intensified and augmented by other media elements. Primary medium and complete media configuration for individual discourse propositions can be differently designed. However, attention must be paid to consistency and fluidity aspect of communication.

Ability to easily mix varied media elements poses a challenge for communication designers to keep the individual media streams spatio-temporally synchronised at lexical, syntactical as well as semantic level. An under-estimate of the effort required to ensure this causes delays in the projects and often a compromise is made to rush and declare the completion of the project. Even a small error is capable of causing an absolute damage to the message. Hence the designers need to be very careful on this issue since the beginning. Formal modeling and representation schemes must be followed in order to design, validate and verify the synchronisation of media streams.

3.0 Learning

Learning is a multistage process. It is highly subjective. One has to be a disciplined learner in order to abstract useful learning. Education and Research in Humanities mostly involves Qualitative Analysis and occasionally uses Quantitative techniques. An interested and oriented learners passes through various stages. As per the ancient Indian tradition Knowledge Acquisition progresses through the stages of *Adhyayan* (Learning), *Bodh* (Understanding), *Aacharan* (Use) and *Prachaaran* (Exposition). Recently some attempts have been made to model the process. Grounding Theory proposed in 1980s is an interesting attempt to understand the process of Qualitative Analysis. Following stages are proposed by this model:

1. Open Coding : The process of breaking down, examining, comparing, conceptualising and categorising data.

2. Axial Coding : A set of procedures whereby data is put back together in new ways after Open Coding, by making connections between categories.
3. Selective Coding : The process of selecting core categories, systematically relating it to other categories, validating those relationships, and filling in categories that need further refinement and development

An almost similar model has been considered by the author for designing the computer based cognition support systems. It comprises of four stages. It is important to note that a definite sequence does not separate the above stages and the learner tends to move back and forth between these stages. These stages are as follows:

1. Experience

Accidental or deliberate experiences offer the opportunities to start rewarding journey of oriented learning. First hand experience is caused in the moments of direct encounter with multi-layered and multi-dimensional reality. Discourses, Museums and Exhibitions try to reconstruct the reality in a focused but limited manner and offer second hand experiences. Different reconstructs need to be presented to different audience depending on their socio-cultural-lingual-academic background. Most effective reconstructs have following features:

- Multi-sensory
- Multi-lingual
- Multi-style
- Multi-layered
- Multi-perspective

This phase does not necessarily require high level of active involvement by the audience and the cognitive load is very low as compared to further stages in the learning process

2. Labelling

Throughout the process of learning, individual meaning components and configurations are labelled. Conceptual labels are placed on discrete objects, happenings, events and other instances. These are classified into higher order, more abstract Categories. Attempts are made to label the following conceptual entities:

- Objects
- Relations
- Order
- Structure

Labels for some key concepts are presented during Discourse but a detailed labelling is explored by the learner during Analysis. After detailed Analysis new labels are assigned by the researchers out of which some may be accepted by fellow researchers and the society at large.

3. Analysis

Only oriented and disciplined learners get interested to carry out a detailed Analysis. *Syllogistic Reasoning* is carried out by the learner to construct a personal piece-wise sequence by gleaning and picking out individual details out of the study

material in linear, non linear and associative manner. High level of learner's involvement is essential for successful progression through this phase. Well structured study material increases the learners' freedom to access the content as per their requirement. Searchability, flexibility and even the utility of information largely depends upon its structure. Sensitive learners are also interested in Dimensionalising the properties of different Categories and like to see the Dimensional Profile for each occurrence of a category.

4. Synthesis

The learner gets an aha! experience, known as *Gestalt Recognition* in the cognitive moment when all pieces of the puzzle come together. The "Whole" which is different from the sum of the parts suddenly becomes visible. An experienced learner creates personal *Cognitive Maps* to unify the total context of the knowledge. Even contradictory experiences can get assimilated without impairing the overall unity. Cognitive Maps are synthetic, higher order meaning configurations and are capable of very efficiently encoding the knowledge. These are generally long lasting and easily modifiable. It is a challenge for educationists to defuzzify the given domains and help the learners to construct their own Cognitive Maps. The proposed model also includes a novel generic knowledge representation scheme to externalise the Cognitive Maps of experienced scholars on any given domain.

4.0 Interactivity Goals

The first generation of technology gave us devices that were primarily extending our limbs to carry out menial tasks easily, rapidly and from a distance. The second generation's focus has also been on supporting the senses. It is the third technological generation which is allowing us to extend our own mental capabilities through computers. The Computer is basically a general purpose representation machine i.e. Simulator. Theoretically, it can be programmed to simulate any defined and analysed Process and Environment. Human creativity and Technological possibilities have gradually led to the deployment of computers in almost any walk of life. Gradual advancements are very rapidly expanding the technological possibilities. It is left to human creativity to use these possibilities to the fullest and use the technology in the most meaningful way.

Study Material includes all forms of Primary as well as Secondary Content. An active learner applies various external as well as internal Cognitive Tools and Processes and explores the study material. A computer aided Cognition Support System should try to simulate and extend these tools and processes as well as offer an integrated corpus of study material. Following are the proposed simulation goals :

A) Study Material

At the General Conference of UNESCO, 1964 a 'Book' was defined as a non periodical printed publication of at least 49 pages, exclusive of cover pages[ ][vi]. Publications of lesser pages were put in the category of 'Pamphlets'. An 'Electronic Book' is expected to offer much more content as electronic encoding facilitates very compact storage. Though no standard has yet been defined, approximately 1000 printed pages worth of content is proposed to be the minimum for an 'Electronic Book'. Any thing substantially lesser than this will fall under the category of 'Electronic Pamphlet'. If required, the constraint of non-periodicity can also be eliminated because of the advancements in computer communication. The CD-ROM content can act as the 'Base Content' and subsequent updates can be accessed via internet through the same user interface. The 'Base Content' could also be updated at a slower pace and new versions can be released periodicity .

Different disciplines give different amount of emphasis to different kind of study material. Generally, learners use following type of study material:

I) Visual Material
   1) Pictorial Material
      - Photographs, Slides, micro-film and other forms of reprographic material
      - Drawings, Maps and other illustrations
      - Film strips, Video and Synthetic Animation
   2) Written Material (possibly multi-lingual and multi-script)
      - Books and Manuscripts
      - Thesaurus and Dictionary
   3) Real or reconstructed 3D objects.

II) Oral Material
- Commentaries (possibly multilingual)
- Recitations / Chanting / Music (possibly multi-style)

B) Cognitive Tools

I) External Cognitive Tools
- Search support Devices, e.g. Catalogues and Indices
- Study Material Inspection Devices, e.g. Slide Viewer, Video Player, Audio Player, Film Viewer and Computer etc.
- Recording Devices, e.g. Notebooks, Drawing Board & Tools etc.
- Measurement and Experimentation Devices
- Cut, Paste and Duplication Devices
- Direct Communication Devices

II) Internal Cognitive Tools
- Multidimensional Mental Space of Analysis
    - Cognitive Maps

C) Cognitive Processes

I) External Cognitive Processes
1) Navigation
    - Linear
    - Non-linear
        - Tree
        - Network
2) Querying
    - Intra-dimensional
    - Inter-dimensional

II) Internal Cognitive Processes
- Pattern Matching
- Recollection
- Comparison
- Contextualisation
- Abstraction

Inter-disciplinary and Holistic studies demand contextual access to visual, oral and textual sources in an integrated manner. Complex knowledge system of Humanities offer multiple hierarchies of closely inter-linked multi-dimensional categories. An active learner makes an intra-dimensional as well as inter-dimensional progression through these categories. Access to related sub-network is made in the context of the chosen categories. In this process new relationships and categories are discovered by researchers. Based on their prior experience and learning styles, the learners tend to choose one kind of resources as their *grounding study material*, while the other resources are used to expand the context. Using the flexibility of computerised databases, it is possible to empower the user to choose any kind of resource material for grounding the studies of other kind of resources.

Flexibility of Mechanised Content Access can only be harnessed by supplementing the Content with a rigorous *Content Structure.* These structural elements represent essential knowledge components and convert a collection of data items into a *Content Corpus* or *Content Base.* An optimised parent-child causal model often results into an over-simplified representation. Further, it is a challenge for educationists to defuzzify the given domains and help the learners to construct their own Cognitive Maps. Subject Experts and System Analysts have to very intensely collaborate to formulate and represent these knowledge structures. Formulation of these structures and representations is the most crucial phase in the process of designing a Computer based Cognition Support System. Success of the project largely depends on the intensity of this collaboration. Hence Designers are advised to specifically focus and be ready to spend substantial intellectual effort in Content Structuring. The computer relies upon these structures to execute various search related tasks and relieves the learner from lot of mechanical activities. This formalisation also helps the subject experts to discover the incompleteness in the data and creates opportunities to complete the same. The proposed model also includes a novel generic knowledge representation scheme to externalise the Cognitive Maps of experienced scholars on any given domain.

As has been discussed in the last section, different stages of learning process demand different kind of support from the learning aids. A complete Cognition Support System should offer support features for all these stages. Hence, the user should be allowed to interact with the system in the following modes :

a) Discourse mode (Story Telling)
b) Exploration mode (In depth Study)
c) Abstraction mode (Internalisation)

A learner model inside the computer can be used to recommend aspects that might have been completely missed or not adequately examined by the learner. An optional feature of On-line Continuous Evaluation can be included to offer feedback to the students.

4.1 Discourse Mode

A persuasive discourse can initiate the user, make him interested in the subject and encourage him to explore the system at more academic levels. This mode can be designed to offer *Experience* and *Labelling* to uninitiated intelligent user. The user should at most be expected to be an active receiver in this mode. An enjoyable discourse can be designed based on one of the following styles:

1. Extended Video Presentation

A System may have multiple Narratives with different focus. In such a situation it is possible to build mechanism for analysing the user's interest and level in order to present the appropriate narration. Alternatively user themselves can choose the appropriate narrative. Several individually useful Sub-Narratives about Key Concepts may be embedded in the discourse. Media rich *Discourse Propositions* consisting of

a sequence of individually significant *Discourse Clauses* need to be carefully planned**.** Narrative Design is a highly creative activity, like a good plot it should have a beginning, middle and an end. It should not be so long that one forgets the beginning before reaching the end. A Discourse Clause can be primarily attributed either by Audio, Visual or Audio-visual Element. Supporting visuals can be synchronised with *Audio Clauses* and audio element can support a *Visual Clause.* A Visual Clause can either be a static visual frame, a series of static visual frames or a kinetic visual sequence. The static frames can themselves have several visual components sharing the frame space. A recorded video clipping or a synthetic animation sequence can be used as kinetic visual sequence. The user is offered the facilities to step through the Discourse Clauses and partially control the speed and direction of presentation.

Only *Key Clauses* are presented during *fast* presentation. The designers are offered freedom to mark all or selected clauses as key clauses. Some frames can be selected to represent the kinetic sequences. More time can be allotted to important frames at the cost of no time to others. This flexibility to present only the partial content of a key clause helps in designing more meaningful fast presentations. This is conceptually different from the *fast forward* facility offered by Video in which frame rate is increased making it almost impossible for the user to register the individual frames. Constrained automation of this selection process is also possible and frames at *controllable temporal distance* or at *scene change* can be automatically extracted as Key frames. In short, following facilities are proposed to be offered:

a) >,< : Next / Previous Clause with synchronised audio-visuals support.
b) >>,<< : Fast Presentation by Forward / Rewind through Key Clauses . The supporting audio is not presented for key visual clauses.
c) || (Pause)
d) ! (Restart)
e) %(Slow motion during the Kinetic Visual sequence without audio)
f) # (Resume the normal mode, available during <<,>>,% only)

2. Interactive Walkthrough

Simulate Exhibition to offer the interactive walkthrough experience through the interface of simulated 3D model. Parallely or alternately offered oral and other kind of resources can help in enriching the virtual experience..

While there is no physical activity being performed by the user in first style of presentation, the user can be allowed to make choices of movement in a simulated three dimensional world. Appropriate mixing of both the strategies is likely to enhance the pleasure of the learner. A simple form of mixing can be based on alternative switching between both the styles at clearly defined 'Entry' and 'Exit' points. This opens up the possibility of activating different presentation clippings of first style at different 'Exit' points of the second. Similarly, occasional limited choices for directing further progression could be offered during presentation of first style as well.

4.2 Exploration Mode

This mode is aimed at offering detailed *Analysis* and in depth information to the interested user. Only active learners get access to this mode. Active participation by the user is expected in order to get the maximum information and knowledge. A navigational approach to information retrieval is facilitated by offering a universal set of controls for examining information of different media types. Special attention is recommended to be paid to maximise the primary content

Following design goals can be satisfied to simulate the Study Room:

4.2.1 Structured Core Corpus:

The content base comprises of core corpus as well as other supporting material. The core corpus is structured as an electronic book which is an organised collection of mutually networked, *mixed media virtual pages*. The author(s) of electronic book can recommend a linear sequence to examine these virtual pages. A Hierarchical structure of 'Chapters' and 'Sections' is also superimposed on the underlying core. It is possible to construct multiple linear and hierarchical structures for the common underlying database. Access to selected virtual pages may be restricted to a particular set of hierarchies. User will then be able to look at the resource material through one of these pre-planned structures. User may be allowed to explicitly make this choice. Alternatively, after initial interaction; user's profile, interests and constraints could be assessed and an appropriate selection be made by computer based on pre-decided criteria.

The virtual pages may contain some or all of the following components:

1. Textual Element(s)
   - Multi-lingual
   - Multi-script
   - Multi-level
2. Oral element(s)
   - Multi-lingual
   - Multi-style
   - Multi-level
3. Pictorial element(s)
   - Multi-resolution

These elements have been proposed to be multi-level to address the needs of multi-level users. This offers the flexibility to different levels of textual and/or oral elements for the same pictorial element and vice versa. Pictorial elements are recommended to be included at multiple resolutions not just in terms of digital resolution but also in terms of content resolution. Following feature can be provided to view and browse through the content of these pages:

4.2.1.1 Configurable Virtual Page Display:

Tools to zoom the pictorial elements is a normal expectation of the users. Choice of virtual page display configuration also helps in accommodating different kinds of user needs. Normally the display area is shared between the textual and pictorial elements. However, user may choose to examine only one of them at a time and assign the complete or larger display area to the chosen element. Other exploration tools listed below continue to be available in such a mode as well.

4.2.1.2 Diverse Information Seeking Strategies:

Choice of information seeking strategies allows the user to smoothly navigate through the Knowledge space. Devices are offered to access the virtual pages and other elements of the study material in linear, associative and non-linear manner. The linear access helps the uninitiated or first time users to navigate through one of the pre-specified sequential paths through the knowledge space at a personal pace. Hot-spots on the elements of virtual pages provide a mechanism to access further explanations and labels in an associative manner. Navigation to associated pages is also facilitated through these hot-spots. Experienced user will use non-linear mechanisms to have faster access to virtual pages based on several kinds of search criteria

4.2.1.2. 1 Linear Access:

The linear and hierarchical structures are used to access the virtual pages. "*Forward*" and "*Backward*" tools facilitate movement through a pre-ordered structure in opposite directions. "*Backtrace"* is not the reverse of "Forward" as it provides a reverse movement through the path traversed by the user before the activation of "Backtrace". "*Resume"* tool repositions the user at the content block visited before the continued activation of "Backtrace". Multiple linear paths and hierarchical structures could be designed around the common corpus for different kinds and levels of users.

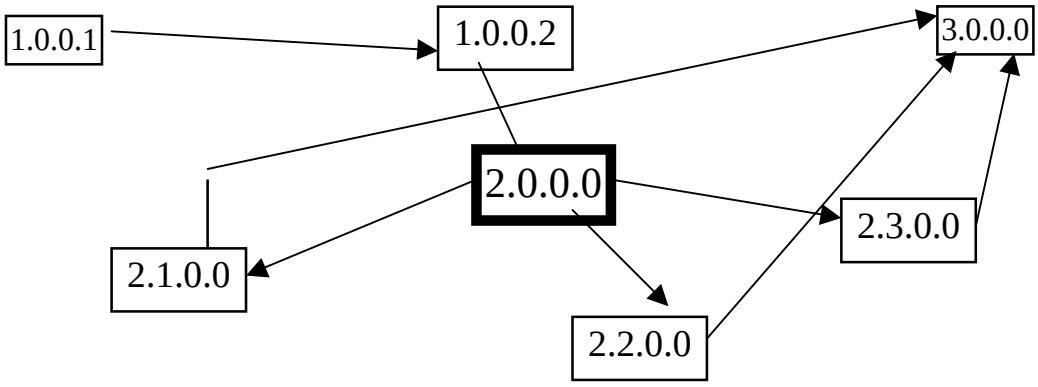
4.2.1.2.2 Associative Access:

Certain portions of an element in virtual pages can establish an association with other pages. Specific entries in other components of the corpus e.g., Glossary and personal notebook etc. can also be associated through some portions. Content authors are recommended to pay special attention towards proposing these associations explicitly. These portions are depicted as *hot-spots* and convert an otherwise hierarchical, linear structure into an *explicit network* of information. Intelligent learners also tend to create *personal networks*. Devices are offered to enable the learner to browse through explicit as well as personal networks.

In textual elements a single word or a small sequence of words can be marked as hot-spots. Single point, rectangular or circular region and even arbitrary shaped objects can be marked as hot-spots in static pictures. The kinetic pictorial elements also have some static objects and background. Similar kind of hot-spots can be marked on these portions. While dynamic hot-spots can be easily created in animation sequences, promising research is on to convert dynamic objects into moving hot-spots even in video recordings. Selected portions of audio clippings can be marked as hot and explanations can be offered during the rendering of these portions.

Explicit hot-spots can offer *explanatory* as well as *navigational links*. Hot-spots can be created in all elements. The source and the destination elements of these links need not be of the same media. Hot-spots in the textual elements can activate pictorial and/or oral elements and vice versa. Explanatory hot-spots in the textual portion may activate relevant excerpts from the glossary. Similar hot-spots in the pictorial elements may just offer labels or another pictorial element. Navigational links can be made to be bi-directional. Multiple destinations can be linked with a single hot-spot to offer a "one to many" kind of relationship between associated node. Content authors can also establish "many to many" kind of relationship.

The collection of virtual pages emerges as networked information structure because of the above mentioned hot-spots and the other linear as well as hierarchical structures. "*Link map*" tool graphically shows the position of the current data block in the networked information space. User have the facility to chose and display the link map around the selected node. Link map also acts as progressively displayed graphical index to the core corpus. The exemplified representation of this "link map" is as follows :



The size of the boxes displaying the current content block no., thumbnail image or the block title whatever applicable is maximum and the size of the rest of the boxes decreases with increasing distance from the current block. It is possible to develop link maps of varying node range and link structures around the common corpus for different kinds and levels of users.

Interested user also constructs personal networks and uses the non-linear search devices to browse through personally established associations. Personal notebook explained later also offers the facilities to record new associations.

4.2.1.2.3 Non linear Search Tools

Structured discourse being followed during the course of linear progression exposes the user with several *labelled concepts*. These concepts often stimulate sensitive learners to suspend or even break the linear progression in order to access specific information. External secondary information structures can be superimposed on the

content of core corpus to offer efficient direct searchability. Following indices can supplement the content of core corpus:

1. Table of content(s)
2. Keyword index
3. Theme words index
4. Frequently Asked Queries
5. Reference list with back citations
6. Multi-dimensional index map(s)
7. Personal Bookmarks

Content based retrieval can be facilitated to allow the user to exhaustively search through content base even without any pre-structured indices. User may be offered tools to specify syntactic content template(s) in textual form. *Free text search* can also enable the user to look for specific virtual pages and/or user's annotations containing a set of words in user defined proximity. One may look for the pages containing the specified words any where in the page, within one paragraph or within a sentence. Search can be made to accommodate variant spellings, synonyms and even word stems. Progressively refinable searches can be very efficiently carried out over the formally structured content. Normalised relational or object oriented structures offer powerful searchability to the user. Structuring Schema is to be jointly worked out by computer and subject specialists. Content scholars then have to classify and organise the information as per this schema. This structuring requires hard work by Content Scholars. Interesting user interfaces can be developed by offering content based search over the non-textual elements as well. Several algorithms for automated image, sound, speech and video analysis have already been developed and active research is going on to improve the technology. Voice, natural language, sketch, gesture, posture and body movement based query input mechanisms can be developed to supplement formal textual templates and more natural interfaces can be offered in near future. Designers are encouraged to explore the possibilities for applying these techniques to offer symmetric multimedia Human Computer Interfaces. A pre-structured encoding can also be used to offer this feature.

Mechanisms can be build to rank the search results in order of *potential utility* as per pre-fixed criteria. Normally search is carried out over a pre-defined space. However, this search space can be put under the control of users. In order to encourage inter-disciplinary studies, it can be automatically outspread to offer *Domain extended search.* Models can be developed to record and maintain user's profile. This profile can be used to automatically supplement user specified search criteria and potentially more useful search results can be estimated.

4.2.1.3 User Trace:

User Trace panel can keep a record of the virtual pages opened for *sufficient time* by the user during the current as well as previous session(s) to allow backtracking through the dialogue path and re-open any page. No record of previewing or backtracking is maintained on the stack of this panel. "Retrace" option can be used to quickly sequence through the preview of all the pages recorded after the selected page. Only important pages are included in the preview sequence activated by "Recap" tool. In addition to pages marked by the author, a page can be regarded as important, if an annotation or a bookmark created by the concerned user is found attached with it.

4.2.1.4 Concurrent and Superimposed Viewing:

Comparative as well as contextual studies can be facilitated by empowering the interested learners to concurrently view multiple pages. " Hold" tools glues the currently active page into the static half of the display space. Further exploration through other pages can continue as before. More than one pages could be chosen to share the static space. The user may decide to "Release" or "Activate" the glued pages. Activation of a glued page causes the positional exchange between the glued and currently active page.

Some elements such as text in different scripts have a continuous association between them. User' movement to different portions within either of these elements can be responded by automatic highlighting or panning of the associated portion in other elements. *Synchronised Concurrent Browsing* in this form is very helpful for reducing *cognitive load* of the user. Pictorial elements of different pages need to be allowed to be superimposed. The users will also be able to record annotations regarding the analysed relationships stimulated by such concurrent and superimposed inspections.

4.2.2 Supporting Corpus:

In addition to the core corpus, compact digital storage makes is feasible to integrate other useful and supporting elements in the corpus. Records in *Dictionaries, Glossaries and Thesauruses* can be made directly accessible from the hot-spots in core corpus. Pictorial and Oral components can be included in the these essential supporting elements. Bi-directional links can be established with the core corpus making it feasible to also use these supporting elements as indices to the core corpus. Similarly *Bibliography* with complete reference can also offer back citation facility. Integrated *Direct communication* tools also make it feasible to remain updated with the authors and also other peers.

4.2.3 On-line Content Creation Tools:

Dedicated tools for *on-line incremental growth* of the corpus may be provided to content editors. Exploring users are provided with *personal notebooks*. User may decide to record personal views while inspecting single or multiple pages. User may create textual and/or graphical annotations. On their creation , these annotations are automatically related with relevant virtual pages by a bi-directional association. If more than one virtual page is concurrently open at the time of annotation, one may associate the annotation with all or selected pages. This also offers an implicit link authoring mechanism. These pages can be opened by the users to recall the '*Context'* of the recorded annotations in later sessions.

User may also desire to include the extracts from the corpus in their notebooks. Annotations are normally not made available to other users, but can be made public by the authoring user. In some cases, annotating user may only be allowed to submit his request to an editorial board which takes the final decision regarding making the user's annotation available to other users. Users can also edit and delete personal annotations. One may decide to assign a *'Theme word' or 'Bookmark'* to an annotation making the notebooks directly searchable through these indices. *Free text search* tools may be provided to allow direct searchability in the notebook as well. Sensitive learners discover new relationships during their exploration. Explicit tools for *on-line link authoring* can be offered to advanced learners.

Users are allowed to take a paper print of individual elements of the corpus. Advanced users often need to prepare lectures and other instructional material out of the content corpus for focused audience. Interested users may construct different sequences of extracted elements from Virtual pages as well as Personal Notebook.

4.2.4 Advanced Data Analysis Tools:

Research minded users may also be offered tools for following academic exercises:

1. Decipherment and Paleographical studies
2. Linguistic analysis
3. Measurements and other geometric analysis
4. Other experimentation tools
5. Direct Communication Tools to send contextual queries to the authors.

4.3 Abstraction Mode

This is a very significant mode as it aims to consolidate the learning and offer the 'Complete Picture' to the user by providing assistance and necessary guidance in *Synthesis.* After synthesis learned user will "see" newer things in the Discourse and Exploration mode. Following objectives should be kept in mind during the design of this mode:

1. Simulate and externalise the Internal Knowledge Structure of content experts in terms of Cognitive Maps to offer the following features :

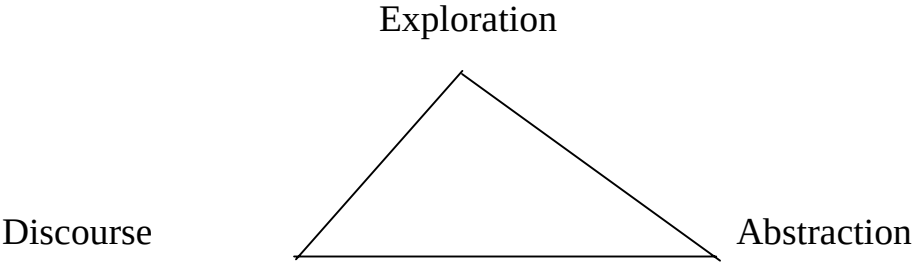
   a) Key Properties (Dimensions)
   b) Key Concepts and their Rendering
   c) Intra dimensional Orders
   d) Inter dimensional Relations

2. Offer Tools for externalisation and construction of Personal Cognitive Maps

4.4 Mode Integration

As has been stated earlier, a learner does not makes a progression through learning stages in a rigid order. An active learner tends to move back and forth between these stages. Hence, during the course of any mode, the user should be offered the facilities for appropriately switching to either of the other modes. Content presented during one mode can be used to as the context to switch to another mode. This facilitates content based seamless integration of all the modes.

Fig 1 : Mode Integration



Following are the proposed strategies for mode switching:

4.4.1 Discourse Mode

As already stated this mode offers a sequence of Audio-Visual Discourse Clauses to orient the learner. During this discourse the learner may get interested in knowing more about any of the presented items. Hence every presented Discourse Clause is appropriately grounded into the database. Additionally, easily identifiable Hot-spots on selected Clauses can also be grounded into the database. In short, devices are proposed to be offered to switch to Exploration mode and enter *Database* at the beginning or at appropriate *grounding position.* Similarly, selected Discourse Clauses and Hot-spots are also Contextualised in the Cognitive Map by highlighting the relevant Key Concept and its associated Concepts along other axes. The user can also switch to Abstraction mode and enter the *Contextualised Cognitive Map* through these gateways. At the end of Presentation, an automatic transition to the Abstraction mode is facilitated by presenting the Cognitive Map.

4.4.2 Exploration Mode

The unit of progression through this interactive mode is Virtual Page. Selected virtual pages and hot-spots are contextualised in the Cognitive Map. Key Concepts of Cognitive Map presented during Abstraction mode are also grounded into these Virtual Pages. Explicit devices are offered to switch to Abstraction mode and enter the Contextualised Cognitive Map. Some virtual pages provide the grounding positions for Discourse Clauses and Hot-spots of Discourse mode. Devices are offered to switch to Discourse mode and start the Complete Discourse from the beginning or start the context related Discourse. If this mode is activated from the Discourse mode, facility to resume the Discourse from the last presented Discourse Clause is also offered. At the end of Exploration, an automatic transition to the Abstraction mode is facilitated by presenting the Cognitive Map.

4.4.3 Abstraction Mode

This mode offers Consolidated Cognitive Map to represent Internal Knowledge Structure in terms of Key Concepts and Inter-concept relationships. All of these Key Concepts are grounded into the Virtual Pages of Database. The Key Concepts also contextualise some Discourse Clauses and Hot-spots presented during Presentation. Some Hot-spots offered during Exploration mode are also contextualised by these Key concepts. Devices are offered to switch to Discourse mode and start the Complete Discourse from the beginning or start the Key concept related Discourse. Other devices are offered to switch to Exploration mode and enter *Database* at the beginning or at appropriate *grounding position.* If this mode is activated from the Discourse mode, facility to resume the Discourse from the last presented Discourse Clause is also offered.

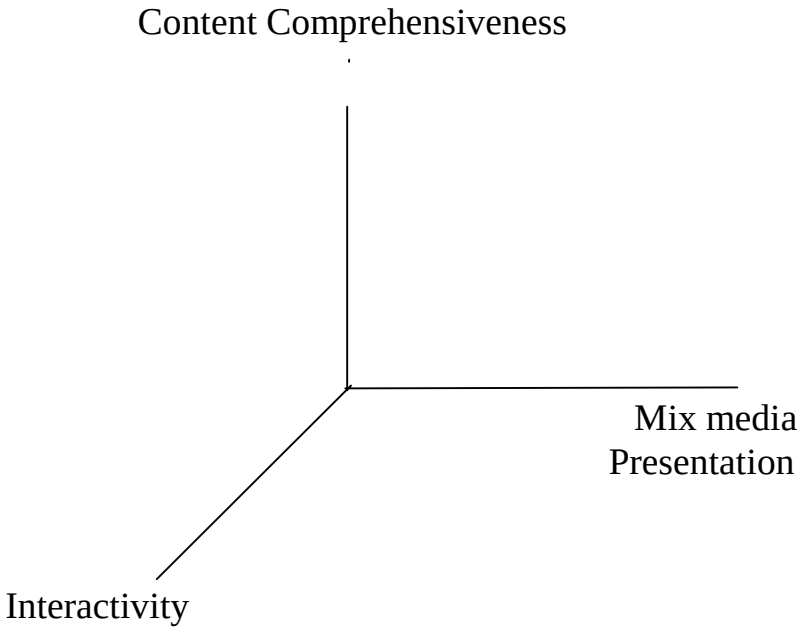
4.5 System Feedback

In order to reduce the cognitive load and disorientation, user need to be supported by System feedback by offering immediate audio-visual and consistent cues of what is happening as a result of user's action. Context sensitive 'Help' is an essential feature for all computer programs. Guided tours for learning about the usage of different devices help the users a great deal. At least Textual explanation of all the visible control devices must be offered as Tool-tip to be displayed on Mouse Roll-over onto the device.

5.0 System Quality

Content Comprehensiveness, Mix media presentation and Interactivity features for Presentation, Exploration and Abstraction are the three major parameters along which the *Quality* of a Computer based Cognition Support System is proposed to be evaluated. It is important to note that their is no conflict among these parameters and they complement each other to improve the overall system quality.

Fig 2: System Quality



Overall system quality is proposed to be quantified as the volume of rectangular box carved out of the proposed three dimensional normalised co-ordinate system i.e.,

$Q_S = Q_C * Q_M * Q_I$ ----------[Eq. 1]

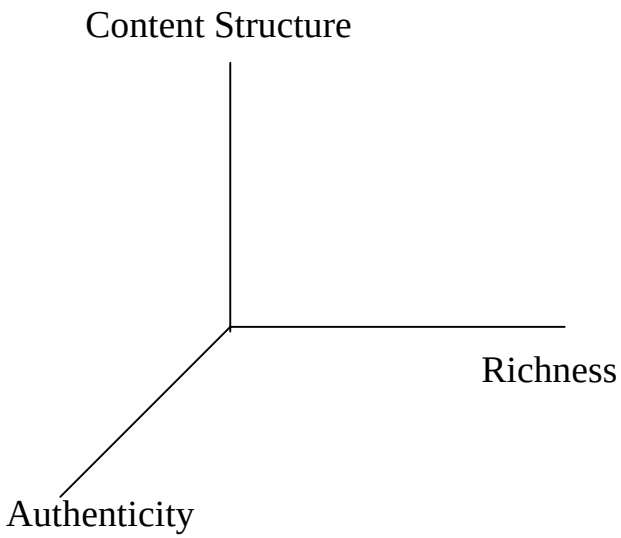
where, Q_S = System Quality [0..1]
Q_C = Quality of Content comprehensiveness [0..1]
Q_M = Quality of Mix media presentation of the content [0..1]
Q_I = Quality of Interactivity [0..1]

It can be seen that even a singular weakness on any of these three fronts will result into a very low quality system. Hence, in order to develop high quality system, it is very important that multi-disciplinary teams closely work towards improving the quality of all the parameters.

5.1 Content Comprehensiveness

Content Comprehensiveness is the most important of the three parameters. It is determined by Authenticity, Richness and Structuring of the content. Well structured study material increases the learners' freedom to access the content as per their requirement. Searchability, flexibility and even the utility of information largely depends upon its structure. Flexibility of Mechanised Content Access can only be harnessed by supplementing the Content with a rigorous Content Structure. The Content Structure consists of internal as well as external structuring elements. Internal structuring elements are embedded into the content itself while external elements provide several kinds of indices for accessing the content.

Fig 3: Content Comprehensiveness



The Quality of Content Comprehensiveness can evaluated as follows:

$Q_C = Q_{CS} * Q_{CR} * Q_{CA}$ ----------[Eq. 2]

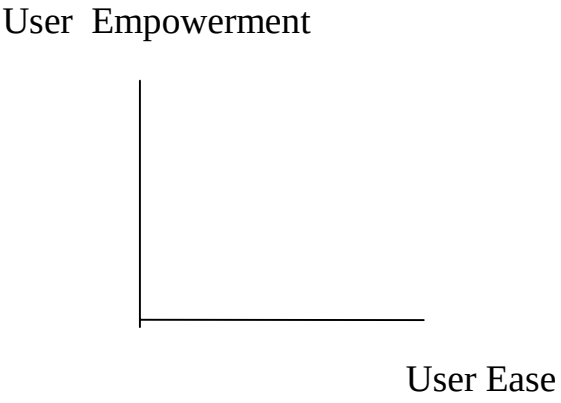
Where, Q_C = Quality of Content comprehensiveness
Q_{CS} = Quality of Content Structuring [0..1]
Q_{CR} = Quality of Content Richness [0..1]
Q_{CA} = Quality of Content Authenticity [0..1]

It can be seen that even very rich and authentic collection of content is not comprehensive until it is structured well.

5.2 Interactivity Quality

As explained in section 4, the computer can be used as meta-medium and interactive devices can be developed to simulate cognitive tools and cognitive processes at different learning stages. These devices provide various kinds of user controls during Presentation, Exploration and Abstraction mode. User-ease and User-empowerment are two non conflicting and complementary parameters.

Fig 4: Interactivity Quality



Level of User-empowerment depends upon the range and utility of devices provided by the system. Consistency of the system with traditional and natural learning tools, system feedback and inter-device consistency determine the degree of User-ease. Quality of system devices can be modelled as follows:

$Q_I = Q_{IP} * Q_{IE}$ ----------[Eq 3]

Where, Q_I = Quality of Interactivity
Q_{IP} = Quality of user-emPowerment by Interactive devices [0..1]
Q_{IE} = Quality of user-Ease of Interactive devices [0..1]

5.3 Mix media presentation

Quality of Mix media presentation of content depends upon media integration and aesthetic appeal of media components.

6.0 Conclusion

Learning advantage of computer supported Cognition is due enhanced *interactivity* between the user and a large corpus of instantly available learning material. Carefully designed *Mixed-media* presentation of information, further increases the learning possibilities. Out of the real design experience on some multimedia projects at CIL, IGNCA, an attempt has been made to develop a generic model design of Computer based Cognition Support System. Interactive multimedia has been proposed to be used as a meta-medium to develop learning aids based on a design model which is primarily an extension of book paradigm to include the features of other educational technologies and the novel possibilities being offered by the computers. The model tries to support the learner through all the learning stages and tries to harness the power of computer technology to develop really useful serious study aids rather than merely enjoyable presentations.

A product development methodology has also been developed for rapid development of multimedia projects based on this model. Development of the Authoring tool based on the proposed model is already underway. Software for several discussed features have already been implemented at CIL by our group and more modules are being gradually added. Though the development tool is not yet ready for usage by other developers without our group's direct involvement , we can use it for the rapid production of very user friendly and powerful Content Exploration Systems on any subject in collaboration with the concerned subject experts.

Previously submitted related documents:

1. Goel Sanjay et al (1995), Concept Paper on Brhadisvara temple.
2. Goel Sanjay et al (1996), Interactivity Design Document of Agnicayan
3. Filliozat P.S. & Goel Sanjay (1996), Content Exploration system on Temples of Karnataka : Software requirement specifications
4. Goel Sanjay (1997) , Concept paper on Digital Kalamula Sastra
5. Goel Sanjay (1997), Content Exploration System on Visvarupa Iconography: Software Requirement specification Document
6. Nagaswamy R.& Goel Sanjay (1997) : Content Exploration System on Brhadisvara Temple : Detailed Menu structure analysis
7. Goel Sanjay & Kersenboom Saskia et al (1997) : CD-ROM on Devadasi Murai

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