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ISSUES AND STRATEGIES FOR COMPUTERIZED DELIVERY OF VIDEODISK-BASED MATERIALS

A rapidly-growing "library" of movies and slide collections is available on CAV optical videodisks. This important resource is expanding even before delivery systems which take full advantage of its power are available. In the future, videodisk material will be delivered by sophisticated computers using a standard set of commands, data structures, and user-interface functions; in the meantime, chaos reigns.

Computers need several hardware devices, software routines, and data resources to control the delivery of videodisk-based materials. They need an interface to extract instructions from the User, a component to translate User requests into an ordered sequence of specific actions, and device drivers to control display by videodisk players. These components can be very simple or highly complex, providing different levels of functionality and "friendliness" to the user.

An ideal delivery system will provide extensive User resources, accessible through a transparent, easy-to-use interface. Disk contents must be described by database structures which capture meaningful, accurate information: computer searches and manipulation of these data representations must yield reasonable, repeatable results. The system should include intelligent routines which minimize demands on the user and automatically optimize the personal environment. Several existing systems make progress towards these goals, and many good paradigms have been refined, but no single design has been overwhelmingly successful.

Videodisk authoring and delivery systems pose critical, unanswered design questions which will bestow immortality on the foresighted and doom the machine-dependent. Proper construction of these resources, and useful routines for their exploitation, also raise difficult issues of perception and cognition. These issues are discussed in the context of an experimental videodisk-based workstation for students, currently being constructed with the assistance of M.I.T.'s Film/Video Section.

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RESOURCES DESIRED BY USERS:

Computer-assisted delivery systems offer a large variety of resources. Users certainly will expect this powerful new medium to support their established research skills and habits; therefore, delivery systems must include modern counterparts of traditional research tools. Where possible, form and operation of these utilities should resemble systems which Users already know and accept.

The Library Model:

One good model of service, widely available and understood by Users, is the traditional Library.

Libraries maintain large centralized collections of books, periodicals, and other text-oriented print media. These materials can be characterized as randomly-accessible, single-user sources, although many of them were constructed with serial access in mind. All were intelligently edited to maintain continuity and reader interest.

On a large scale, Libraries offer "Card Catalogs" and "Citation Indexes" which span a large range of self-contained, individual volumes. These utilities are searched by Author, Title, or Subject; they indicate specific references, and provide short, informative descriptions to help refine the choice of specific volumes.
On a smaller scale, individual volumes contain several formal resources to help users access their contents. "Page numbers" and "punctuation" provide a co-ordinate system which allow materials to be precisely located within a volume. "Table-of-Contents" and "Index" sections are searchable by Title and Subject keywords; when chosen, they point to specific locations in a book. "Footnotes" contain comments by the author, and references to supplementary material located elsewhere.

Users doing Library research on a specific topic traditionally perform several actions. First, they will consult the "Card Catalog" and "Citation Index" to find possible references and their locations. Users will record this list in their personal notebook. Then, these references are retrieved and examined: the User may casually "browse" through them, read them completely, or search the "Table of Contents" and "Index" sections to locate the specific material of interest. Users analyze this material and paraphrase it in their personal notebooks; in addition, they may "Xerox" and keep exact copies of selected materials. A destructive user may even use a pen to "mark" interesting material in a volume for easy recall, and could write personal "comments" in the adjacent margin.

The TV Model:

Commercial Television presents another well-known and widely-available model for delivery systems; when hooked to a video recorder, this system demonstrates several desirable features. Television stations broadcast in real-time to many simultaneous viewers. There are several channels available; each offers unique, serially-delivered programs which were edited by experts to maintain continuity and viewer interest.

Typical TV audiences have access to a "TV Guide," which is an index of pre-made programs and movies scheduled for broadcast. These indexes can be searched by Time, Title and genre; a successful query points to the Channel, Date, and Time where desired programs are shown. Users without an index can sample the currently-running programs by briefly "flipping" through several channels.

Once a program is selected, Users can set their monitor to the specified channel and passively watch a pre-recorded presentation; some users record this material for later, personalized use. Alternately, a viewer may "browse" through portions of several available programs before finally watching one at length.
The TV broadcast includes material supplemental to the central program: "News Bulletins" provide occasional reminders of the larger World context; "Previews of Coming Attractions" enticingly showcase alternative materials available through the delivery system; and "Commercial Messages" suggest other activities or topics the viewer might pursue. Close-captioning provides a written transcript of audio information as a supplement to hearing. If the viewer is part of a "Nielson Family" or subscribes to a pay-as-you-use cable system, a device keeps track of which programs the viewer has seen.

The Butler Model:
Butlers are intelligent servants which closely resemble the User in form and understanding. Butlers are highly motivated to serve as unobtrusive, labor-saving intermediaries between the User and other systems; they are familiar with available resources, and are very good at interpreting requests for service. Most importantly, Butlers are very familiar with the User's preferences and habits; often, they can anticipate User needs and prepare to meet them without being explicitly told.

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SYSTEM SOFTWARE FUNCTIONS:

The "Library", "Television", and "Butler" models suggest several data resources and functions worthy of computer-aided delivery systems. In outline form, these are:

a). USER RESOURCES:
- * footnotes
- * comments
- * references
  - -dossier files
  - -maps
  - -diagrams & illustrations
  - -supplemental text sources
- * segment-tagging
- * personal "aliases"
- * transcript of audio
- * search facility
- * simulation modeling interface
- * word processor

b). AUTHORING RESOURCES:
- * disk content logging
- * sequence editor
- * icon construction

c). USER INTERFACE FUNCTIONS
- * automatically adaptive environment
- * work session log
- * cinematic "expert editor" delivery
  - -two identical disks allow "seamless " edits
- * window/menu display manager
  - -live video
  - -stills
  - -grabbed frames
  - -painted graphics
  - -text windows
  - -menus
    - --text-based
  - --icon-based
- * manual disk controls
- * database query constructor
  - --keyword matching
  - --inference search
  - --icon search

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DESCRIPTIONS OF SYSTEM SOFTWARE:

USER RESOURCES:

1). Footnotes Handler:
If supplemental information sources are "footnoted", the User can display the contents of footnotes on demand. If the footnote cites other materials which are available to the system, the User can also can call-up and display the cited references.

2). Comments:
Users and Domain Experts can attach text comments to selected segments; these are available for display when the segment is shown. Many Domain Experts can provide comments for any specific segment: Users can set environmental parameters to automatically display or ignore comments from individual Experts.

3). Supplemental Reference Lookup:
Often, there will be useful supplemental documentation which is available to the system. Detailed dossiers on people, places, issues, and objects; maps of the "current" location in the world; simulation modeling tools for scenario analysis; quizzes; and a host of other available resources can be conditionally enabled. This facility assists call-up and display of these sources on demand.

4). Segment-Tagging:
Users may wish to "tag" interesting material for convenient recall in the future. A journaling or Expert Delivery system may wish to "tag" material that the viewer has already seen to avoid excessively repetitious presentations.

5). Personalized Alias Construction:
Alias Construction software allows the attachment of personalized "aliases" to any object. These are used for convenient reference and recall of re-named objects; the system automatically substitutes the longer, formal names when aliases are used.

6). Audio Transcript:
A transcript of the disk's current audio track should always be available. Ideally, this text would be available for screen display with the current word {indexed to frame numbers) highlighted in color for easy identification and tracking. This resource would be helpful where the audio is difficult to understand; in addition, it is a data resource which can yield important information when searched in parallel with the videodisc's "content" database.

7). Database Search Query Builder:
A special, "user-friendly" front-end should be available to construct searches in the database's inquiry language. In addition to allowing specification by typed text, queries might be constructed by choosing from menus of pictorial icons, or by applying other representational shorthands. This software also handles conversion from symbolic choices or "aliases" to the expanded verbiage of database query-language search strings.

8) Simulation Modeling Testbed:
Processes in economics, social science, and other fields can be simulated with the computer. These models can incorporate speculative rules, principles, and relationships of unknown validity. This software extracts data from a database, a specified file, or direct User input, and uses it to run the simulations. This flexible testbed allows speculative models to be evaluated and refined using "real world" or constructed data. Also, accepted models can be used to extrapolate "missing" data not explicitly contained in the database, and to explore "cause and effect" relationships.

9). Word Processor:
Access to a word processor provides the User with a "personal notebook". This can be used to save excerpts of selected text resources, User-written paraphrase of that material, and User comments. It can also contain database search specifications and pointers to chosen disk footage for easy recall or use as "video footnotes".

AUTHORING RESOURCES:

10). Disk Content Logging Tools:
User-friendly routines allow easy writing and editing of database records. These facilities minimize the typing aspect of data entry by presenting appropriate Master Lists as "menus"; the chosen value fills the field. In some cases, these may be menus of Picture Icons, which are replaced by alphanumeric "alias" values when chosen. Also, the system makes rich use of defaults; some fields take values from current Environment or Device Driver parameters, without requiring keyboard entry by the User.

11). Sequence Editor:
Domain Experts assembling stories or classroom materials, frequently need to construct special "canned movies". This is accomplished by searching out relevant video segments, trimming them, arranging them in order, and "splicing" them together. This software eases the task of constructing and handling an "Edit Decision List", which is the system's internal representation of "canned" movies and sequences.

12). Personalized Icon Construction Tools:
Icon Construction software helps Users build personalized icons and attach User-defined "alias" names to any object. Constructed Icons include compositions of text, graphic images, or grabbed and shrunken video frames. When they exist, these personalized Icons replace the default System Icons for display.

USER INTERFACE FUNCTIONS:

13). Adaptive Personalized Environment:
Many environmental parameters exist which describe User needs, Preferences, and states. Some preferences are explicitly specified; others are installed by default. The intelligent delivery system observes a User's actions and choices; deduces preferences or habits, and uses these conclusions to "fine tune" the optimum personal environment.

An example: the intelligent delivery system offers "Long" Versions of "canned" movies by default. It observes the User

13). Adaptive Personalized Environment (continued)

choosing the "Short" Versions instead. After three consecutive occurrences, the APE concludes that the default value of variable "Preferred Movie Length" should be changed from "Long" to "Short". The update is performed automatically, without being explicitly ordered by the User.

Another example: the delivery system "tags" material as it is delivered to the User. By considering how often specific footage has been shown, the delivery system can adjust its presentation to avoid excessive repetition.

14). Work Session Log:
This is a journaling feature which allows users to file a copy of important interactions experienced during a work session. Interesting paths through the material can be recorded here and later re-created; personal comments and references attached to specific material can be saved to span several work sessions through this facility. Contents of this "log" can also be linked to a word processor, which can function as a "personal notebook" for users assembling research. Additionally, Course Administrators can use this record to see if students have “done their homework" and evaluate their progress by examining the duration and quality of student interaction with assigned material.

15). Cinematic Expert Editor:
In Search mode, database queries yield a list of appropriate segments for display. However, this machine-generated list lacks the human style and intelligent editing of the “canned" movies. To massage an arbitrary stack of segments into an aesthetically tolerable movie sequence, the delivery system should include "Expert Editor" software. This facility would be an Expert System which applies editing rules, strategies, and style paradigms (based on image content and composition) to intelligently edit segments into a palatable "movie". An optional mode for this delivery system co-ordinates two disks for “seamless” intercutting.

16). Flexible Windowing / Editing System:
A window manager, such as "X" , controls display of a rich variety of graphics, text objects, and processes. Live video, text menus, icons, and other objects must be flexibly reconfigurable on the monitor under software control.

17). On-Screen Videodisk Player Controls:
Manual control of all Videodisk Player functions should be available on demand, either through the-keyboard, an on-screen Icon Menu, or other customized controllers.

18). Flexible Database Search Query Builder:
Database searches require precise specification; however, User-provided criteria are often incomplete or imprecise. Special software is needed to extract User needs from typed text, menu choices, and other input; this information is then interpreted and translated-into the precise verbiage of the database query language. These queries usually initiate exact-match keyword searches or key-value comparisons. By using a special "Dictionary" and "Thesaurus", the Inference Search module expands the verbiage of a database query to include synonyms and "near-miss" words or concepts. By this device, the User attempts to retrieve relevant data even if a "bad" keyword is specified.
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A TYPICAL WORKSTATION CONFIGURATION:

The current generation of stand-alone videodisk workstations resembles this generic bundle of hardware and software:

Hardware:
A). A microcomputer, interfaced to a Communications Network
B). One or more Computer Monitors (RGB graphics preferred)
C). One or more Videodisk Players (IEEE-488 or RS-232 interface)
D). Graphics board with Frame Grabber (TARGA or PARALLAX)
E). several Communications Ports (IEEE-488 or RS-232 or other)
F). Input Devices (Mouse or Tablet or Joystick or Shuttles)

Software:
G). Computer Operating System (UNIX or DOS)
H). Database Management product (INGRES or DBASE)
I). Device Drivers (Videodisc Player controller, Network Communications driver, Graphics Board functions)
J). Programming Language Compiler (LISP or C)
K). special software User Resources
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SYSTEM DATABASES:

The structure of database resources ultimately determines the form and usefulness of most User functions. Delivery systems manipulate three primary data resources: the audio and visual information captured on the videodisk itself; the computer database describing videodisk contents, indexed by frame numbers; and supplementary material related to the videodisk but not directly describing captured images. Important issues of database design include, in outline form:

A). DESIGN OF SUPPORTIVE DATABASES:

* Where do they live?
  - Encoded on the videodisk itself
  - Local computer storage
  - Remote computer storage
  - Distributed computer storage

* Who can change them?
  - Nobody
  - Anybody
  - Superusers Only
  - Only Full-sized Personal copies are changeable
  - Only Personal CHANGES are stored
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* How are they searched?
  - dynamic search for exact keyword match
  - dynamic search for exact icon-alias match
  - dynamic inference search
    --Dictionary and Thesaurus expanded keyword

B). DATA REPRESENTATIONS OF MOVING CONTENT:

* What information should be represented?
  - segment "name"
  - start/end frame numbers
  - lists of participants and objects
  - descriptions of scene and situational content
  - descriptions of actions
  - descriptions of audio content
  - descriptions of visual composition and content
  - descriptions of interpreted meaning

* What record structure is appropriate?
  - simple flat-file fixed-format records
  - Artificial Intelligence techniques and structures
    -- primitives library
    -- master lists
    -- scripts
    -- dictionary & thesaurus

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DESIGN OF SUPPORTIVE DATABASES:

1}. WHERE SHOULD DATABASES LIVE?

There are many important trade-offs involved in deciding where a database is stored and managed; memory space, speed, hardware needs, and flexibility of data access are all critically influenced by this choice.

a} ENCODED ON THE VIDEODISK ITSELF:
Database descriptions of videodisk contents require a tiny amount of "real estate" compared to the storage of video frames: several megabytes of ASCII text consume less than 1% of the available space. The amount of storage space available on the optical videodisk usually dwarfs the capacity of the computer's RAM and magnetic disk. However, the usefulness of this strategy is limited by the format of the videodisk. Hybrid disks combining digital and analog information are rare and need special equipment to use. Generally, if the video is stored in analog form, the descriptive data must also be analog; if the images are digital, the descriptive data is also digital. Extraction of this data requires a special interface, decoding circuitry, and extra processing. For fast search and access, the data must usually be downloaded into the host, which negates the idea of saving computer space.

b}. LOCAL:
Good "Personal Computer"-scale database-management software is available, although it lacks many of the functions and features offered by big-machine versions. Local ownership of a database allows faster data retrieval, but searches and other processing are slow on small machines, and databases larger than a few megabytes will exceed the capacity of the computer. Owners can make personal changes to the data which may be forbidden on a communally-owned copy. Most importantly, local database management can avoid the problems imposed by Network Communications, incluc1ing transmission-time bottlenecks and loss of control over peripheral devices connected to the local host.

c). REMOTE:
Substantial databases must live in the big-computer environment of enormous disk storage, mighty utilities, and powerful processors. Database managers at this scale have many interesting features and functions. Storage capacity may allow users to own personal, modifiable copies of a protected Master database. Unfortunately, remote network communication complicates operations and degrades performance; often, the network server can turn the most sophisticated workstation into a dumb terminal, unable to run processes locally or access devices plugged into it. This may even require videodisk players to live remotely, transmitting signals across a broadband cable to local monitors.

d). DISTRIBUTED:
Distributed resources present very interesting trade-offs. Access to a variety of equipment allows increased flexibility to "use the right tool for the job." By strategically splitting a Master Database parts and mounting the parts on several machines, it is possible to maintain databases of staggering size and to run processes "in parallel". Unfortunately, coordinating several devices in a distributed system can be a difficult juggling act, and performance is invariably slowed.

A special application of distributed processing is the Differential strategy, which operates two databases in parallel: the Master Database, which is permanent and unchangeable, and a Supplemental Database, which contains only the User's personal CHANGES to the Master. When the Master Database is queried, the Supplemental Database is also searched; entries in this personal Supplement take precedence over Master Database fields. In this way, the Master Database remains pristine and yet it appears to contain the User's individually-updated data values. With this strategy, Users can maintain personal, modified versions of a write-protected database in drastically less space than a full-sized copy would need. However, it increases the work needed to process queries.

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2). WHO CAN CHANGE THE DATABASE?

a). NOBODY:
The Master Database cannot be modified. A single Database can safely serve all Users only if personal changes are forbidden; otherwise, the database is rapidly-mutating and dangerously inconsistent. However, many Users will need some mechanism to store comments and other personal database modifications; a good system must provide other functions to fill this need.

b). ANYBODY:
Users need to have some way of storing comments and personalized updates to Master Database information. However, it is dangerous to give numerous Users power to change a single central resource; it would become unstable, erroneous data might find its way in unnoticed, and query responses would be inconsistent over time. It would he preferable to give most users writable access to a copy of the Master Database, and keep the original intact; a review process could determine if User contributions were worthy of institutionalization in the Master Database.

c). SUPERUSERS ONLY:
Special Users can modify the Master Database. Perhaps a Disk Designer or Domain Expert needs this special ability, but it is preferable to let them work on a copy of the Master Database; an orderly review process could decide if their changes are worthy of inclusion in the Master, and the possibility of spurious entries is reduced.

d). ONLY FULL-SIZED COPIES ARE CHANGABLE :
Individual Users own a private copy of the Master Database, to be altered and modified at will. This is the most desirable solution in terms of simplicity, speed, and flexibility of use. Unfortunately, the host computer may not have sufficient capacity to allow these full-sized copies.

e). ONLY PERSONAL CHANGES TO THEMASTER DATABASE ARE STORED
The Differential strategy. Two databases operate simultaneously: the protected Master Database, and a Supplemental Database of User modifications to the Master. A query searches both databases: values returned from the Supplemental Database displace values returned from the Master. In this way, the results appear as if the Master Database has been updated by the User: however, it remains intact. The Supplemental Database needs less space than a personal copy of the Master Database, but increases the work required to process queries.

3). WHAT FLAVORS OF DATABASE SEARCH ARE AVAILABLE?

a). EXACT KEYWORD MATCHING:
Of course, this is the usual flavor of database search.
To return a positive result, Keyword search requires an exact match of the specified search string with a string in the key field of a database record. If the match is not exact, no data is returned. Misspelling of keywords during database record entry or the choice of an "inappropriate" search string will result in an unsuccessful query. Since the use of language is not standardized, the requirement of exact-match for keywords can seriously hinder performance.

b). ICON-SPECIFIED SEARCH:
Menus of pictorial icons are offered; choices are replaced by their alphanumeric "alias" values and assembled to form a database query. This system for specifying a search string minimizes keyboard entry, and certainly works for simple requests. However, pictorial icons can be ambiguous or vague, and experiments are required to test their value for specifying complicated searches.

c). INFERENCE SEARCH:
By using a specialized Dictionary and Thesaurus, the Inference Search module expands the verbiage of a database query to include synonyms and "near-miss" words or concepts. With this device, the User attempts to retrieve relevant data even if a "bad" keyword is specified. The Inference Search module also attaches a "goodness of match" rating to each of these retrieved values to help evaluate the results.
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DATABASE REPRESENTATIONS OF MOVING IMAGERY:
The basic unit of interest when dealing with motion picture and video imagery is the "shot", defined as a continuous series of related frames.

For frame-addressable media, the simplest representation of "shots" is a list of "frame-in" and "frame-out" addresses; it may also include arbitrary "shot names". This form uses a single record in the database to describe each shot.

More useful representations of videodisk material include some description of "observational" and "interpreted" content. "Observational" content is objective, factual information unambiguously present in the material, such as: who is in the picture, the color of a building, etc. "Interpreted" content is not explicitly stated by the material but is still present, such as: "cause-and-effect" relationships, motivations, and emotional states. "Interpreted" data is a broad category, and items may have considerable "uncertainty" associated with them; therefore, system designers must seriously consider whether both types should live in the same database, or should be maintained "in parallel".

Computer-aided delivery systems can exploit several types of descriptive data. Useful information includes: lists of participants and objects, descriptions of setting and situation, actions, composition and content of visual images, audio track information, and interpreted conceptual content.

Most existing delivery systems use a flat-file database structure where each shot is described in a single record. This scheme reserves fields of fixed position and size for various "content" parameters. Although search and retrieval of these records is relatively fast, this structure is inadequate to represent complex content.

Linear programming, mathematical modeling, and Artificial Intelligence research have developed powerful paradigms for describing objects, actions, and strategies. These require extensive resources, considerable processing, and a variety of flexible data types which flat-file systems do not; however, these methods do a good job of describing complex, real-world situations.
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FRAME-BASED STATE MDELS OF OBJECTS AND PROCESSES:

Many types of models can be created and run to aid presentation of videodisk-based material. Models of "Database Access" can construct excellent queries with a minimum of User input. Models of "Cinematic Editing" can construct aesthetically-appealing presentations from lists of raw shots returned by database searches. Models of "Problem Solving" can help the delivery system determine what information it needs to solve problems, where to find it, and techniques to apply. Models of "the User" can help the system anticipate needs, cue-up services in advance, and personalize the environment. Models of "Human Behavior" and other systems can be applied to examine the content-description databases and hypothesize about cause-and-effect relationships, motivation, plans, etc.

Traditional Linear Programming strategies create mathematical models of systems for analysis. Generally, this involves: identifying major input, output, and system variables which describe the chosen object or process; appraising the limits and "rest values" of these variables; and embodying various rules and relationships among the variables in a matrix of simultaneous linear equations. These models are run on a computer using real or speculative data; the resulting "states" of important variables provide a basis for evaluation and prediction.

"Frame Theory" adds a layer of convenience to this process. A library of generic "Primitives" allows the User to invoke a complex "standard" model with a single word; special operators update the "default" values of state variables or relationships to define the specific instance of a "primitive" type. Generally, "Primitives" include data structures ("Frames") embodying the important state variables of an object or process, and default values which may be easy or difficult to dislodge. "Actions" usually manifest themselves by value changes of state variables; a special type of data structure is used to affect these changes. "Primitives" may also include a "script", which is a conditionally-ordered list of "actions" to be performed.

Additional facilities extend the usefulness of this design strategy. A "Dictionary" contains definitions of specific objects; it invokes the necessary "primitives", and includes "modifiers" to customize those generic forms into precise descriptions. A "Thesaurus" contains convenient cross-references to existing near-miss concepts, similes, and analogies. Both of these utilities are useful to recover from badly-worded User requests; if the system is stymied, they can provide fresh approaches to solving a problem.

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DATA RESOURCES:

Edit Decision Lists
      - canned sequences

Master Lists
      - people
            * individuals
            * groups
      - places
      - things
      - issues
      - projects
      - thematic roles

Disk Content Descriptions
      - conceptual content
            * situations
            * actions
            * cause-and-effect
      - audio
      - visual image
            * composition
            * content

Text Blocks
      - footnotes
      - comments
      - reference files
      - audio transcript

Primitives Library

Dictionary

Thesaurus

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