Using an Object-Oriented Paradigm to Organize, Manage and Present Scientific Information for Researchers in a Scientific Center

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1. Introduction

The National Science Foundation (NSF) is a United States government agency established to promote research, development and education in science and engineering. NSF funds scientific research through research grants to universities. Through this funding, NSF funds the Engineering Research Center (ERC) program. There are approximately 20 plus ERCs throughout the United States. ERCs focus on the definition, fundamental understanding, development, and validation of the technologies needed to realize a well-defined class of engineering systems with the potential to spawn whole new industries or radically transform the product lines, processing technologies, or service delivery methodologies of current industries. Also, ERCs must fulfill NSF's goal to increase the diversity of the scientific and engineering workforce by including all members of society regardless of race, ethnicity, or gender in all aspects of the center's activities. In an effort to fulfill this mission, ERCs produce an enormous amount of data and information. This means the amount of information to be considered by this research has the potential to be exceptionally large. Just sheer volumes can introduce an added complexity in determining a solution for the ERC information design problem. Therefore, systems, subsystems, segmentation and multiple approaches to breaking down the information are very appropriate for this research. In addition to large volume data problems, researchers with an ERC tend to do very little collaboration with other researchers in the ERC. Little or no collaboration can lead to less productivity and duplication of effort.

The purpose of this paper is to report the results of the research carried out to address the information design issues associated with organizing and managing large volumes of scientific information over extended periods of time (e.g., a ten year period) within scientific centers. This data management solution is designed to improve researcher productivity and collaboration. To support these information processing needs across different types of scientific centers (e.g., medical, manufacturing, environmental, etc.), the design had to have a universal means of management and presentation of the scientific information. In an effort to address this goal, the primary agent of design is an Information Design Pattern (IDP). The IDP was developed based upon a normal scientific poster pattern, augmented with multimedia content. A scientific poster is a document that can be used to summarize and communicate any type of research information. Also, poster patterns are not new or unproven but have been applied by many different researchers over a long period of time to efficiently communicate scientific information. Scientific posters can provide the base for the development of effective scientific IDPs. The scientific IDPs proposed in this research are expressed in terms of structured layouts, short narrative discussions, images (2D and 3D), graphics, diagrams, audio, and full motion video. The proposed solution for the scientific center information overload problem is delivered as a website for researcher interaction and information access.

2. Definition of Terms

Information[1]: data or facts that have been organized and communicated in a coherent and meaningful manner.
Information Design[1]: is concerned with transforming data into information and making complex information easier to understand and use. The information design process considers the selection, structuring, and presentation of information in relation to the purposes, skills, experience, preferences and circumstances of the intended users.
Information System[19]: a data processing system that collects, processes, edits, stores, transmits and supplies data relating to a specific application area.
Information Engineering[20]: a set of formal methods for planning, analysis, design and construction of an information system. The process will include the design and architecture of user interfaces, databases, networks and web sites.
Object-Oriented Analysis and Design (OOAD)[12]: is a methodology for developing software where models are developed of real-world problems and solved in real-world ways where the analogy is carried from problem definition through implementation of the application software.
Object-Oriented Model[10]: an abstraction built to understand a problem before implementing a solution. The model is structured using classes/objects and the relationships manifested between classes. Classes are built around real-world attributes as well as their real-world operations.
Object-Oriented Development[12]: a conceptual process, independent of programming, used to abstract and model problem and solution concepts and communicate them for greater problem understanding.
Information Design Pattern[3]: is a record of the design of information gained through experience where this record systematically names, explains, and evaluates an important and recurring information design.
Joint Application Development (JAD) Session[15]: a structured workshop where users and developers come together to plan projects, design computer systems, or make business decisions. This workshop involves a detailed agenda, visual aids, a facilitator who moderates the session and a scribe who records the agreed-upon requirements.

Industrial Strength Software[13]: a sound robust piece of software that has been thoroughly tested in live user environments for extensive periods and has built-in safeguards against system failures.

3. Brief Description of Figures

- Figure 1: Information Design Pattern (IDP) Definition – gives a formal definition of the information design pattern structure.
- Figure 2: Base Graphical Information Design Pattern Object Structure - shows an information design pattern with a breakout of its segments.
- Figure 3: Information Design Pattern Building Block Objects – gives a list of the possible objects used for creating design patterns
- Figure 4: Object-Oriented Information Design Pattern Model – shows the class and objects used to define the object-oriented model of the IDP.
- Figure 5: Research Methodology – a flow diagram of the activities performed to analyze, design and implement the research information design solution.
- Figure 6: Scientific Information System – the scientific information system solution.
- Figure 7: OODB For Information Design Patterns and Multimedia – depicts the OODB used to archive the information design patterns and multimedia data.
- Figure 8: Keyword search schemes – diagram showing 3 example search schemes for an OODB.
- Figure 9: Ten Year Scientific Information System Archive – diagram showing a 10 year research archive and the researcher interface.
- Figure 10: Scientific Information System Website: a depiction of a scientific information website.

4. Objectives

The primary objective of this research study is to develop a solution for the ERC information overload problem as it relates to researcher communication and collaboration through intelligent information design and presentation techniques. The goals addressed by this research are outlined below:

1. Develop an information design pattern[3, 4, 5, 6] that:
    - uses scientific poster technology as a base,
    - reflects the input of ERC scientists,
    - is usable across all ERCs,
    - increases the communication, collaboration, and productivity among ERC scientists.
2. Develop software that automates the design pattern development process.
3. Use information design patterns as a window or link into the details (e.g., publications, reports, manuals, video clips) of each scientist's research.
4. Develop a product capable of storing 10 years of ERC research information design patterns which can be searched and provide high quality results available for researchers within/without each ERC.

5. Develop an ERC website where researchers can query the studies of other scientist in their field within/without an ERC.

5. Solution Description

5.1. Scientific Poster Patterns

In an attempt to find some commonality among the data in scientific poster patterns[7, 8, 9] (i.e., 100 poster patterns covering a 2 year period), the poster patterns designed by researchers at Johns Hopkins University (JHU) were analyzed. In this research, no commonality surfaced, however, it became clear that the poster structure[9] itself was the solution we were searching for as opposed to a common pattern. It was this realization that really gave direction to the research. Not that the poster was the actual solution, but it could become the base for a solution. For example, the poster is a universal structure used to communicate research results. It is a structure that can normally be fully read in less than 10 minutes thereby efficiently communicating information. Also, designs for scientific posters are not new or unproven, they have been used to communicate scientific information over a long period of time, researchers are very familiar with the process used to develop scientific posters, and scientific poster do not describe any specific implementation of scientific research. As a means for information design across many different ERCs, engaged in all types of research, a scientific poster structure seemed to be a natural for an information design pattern.

5.2. Information Design Pattern (IDP)

Expressing proven techniques as IDPs makes them more acceptable within a community of users. The scientific poster pattern structure provides this acceptability for an ERC IDP. The ERC IDP is defined by the structure outlined below (figure 1).

1. Name of IDP

2. Graphical IDP Structure

3. Definition of IDP Building Object Segments

4. Object-Oriented Model of Graphical IDP Structure

Note: ***The Scientific IDP's proposed in this research are expressed in terms of structured layouts composed of segments of short narrative discussions, images (2D and 3D), graphics, flow diagrams, and full motion video (i.e., composed of full multimedia technology).***

FIGURE 1: INFORMATION DESIGN PATTERN (IDP) DEFINITION

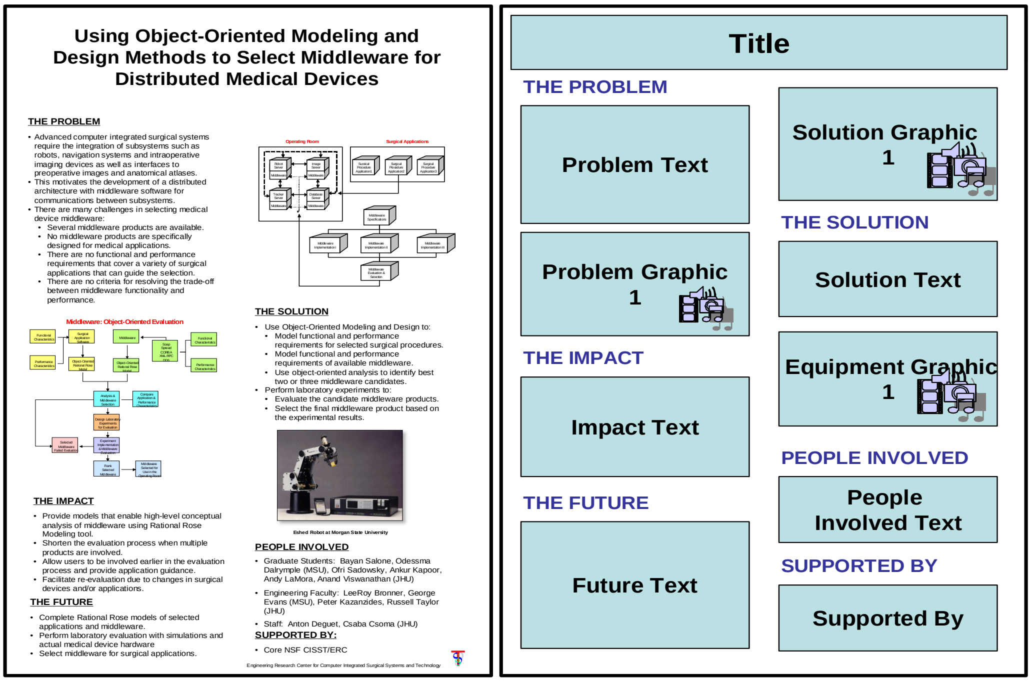

FIGURE 2: BASE GRAPHICAL INFORMATION DESIGN PATTERN OBJECT STRUCTURE

- Title
- Problem
- Solution
- Impact
- Future
- Support
- Researchers
- Publications
- Image
- Video
- Audio
- Graph
- Flow Chart
- Table
- Background
- Purpose
- Hypotheses
- Materials
- Methods
- Results
- Conclusions
- Bibliography
- Abstract
- Introduction
- Instrumentation
- Procedure
- Discussion
- References
- Acknowledgements
- Architecture
- Modifications
- Data Presentation
- Related Work
- More Information
- Numerical Simulation
- Applications
- Design
- Algorithm
- What Learned
- Hardware Circuit
- Context
- Objective
- Rationale
- Methodology
- Justification
- Theory
- Recommendations
- Terminology
- Experimental Work
- Study Protocol
- Goals
- Aims
- Disclaimers
- Comments
- Collaborations
- Known Relationships
- Sustainability
- Contact List
- Strategy
- Origin of Data
- Comparison/Previous Results
- Other Applications
- Predictions
- Sample Preparation
- Approach
- Overview

FIGURE 3: INFORMATION DESIGN PATTERN BUILDING BLOCK OBJECTS

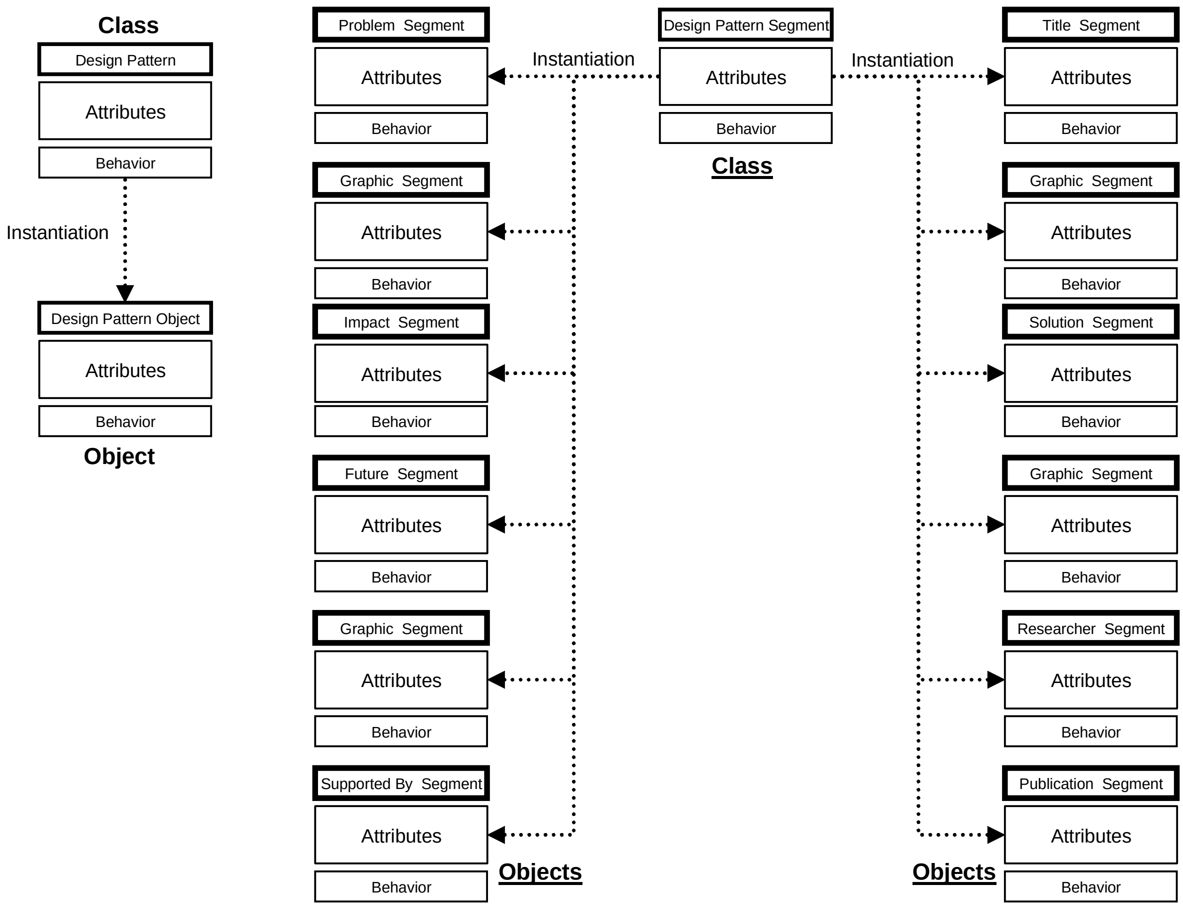

FIGURE 4: OBJECT-ORIENTED INFORMATION DESIGN PATTERN MODEL

The structure is defined by four entities, a name, a graphical structure (figure 2), a set of building block objects (figure 3), and an object-oriented definition (figure 4) of the IDP. The graphical structure pictorially defines the details of the IDP. The building block of objects used to develop IDPs provides a means for each ERC to customize an IDP to fit their needs. The object-oriented model provides a structure for understanding the IDP and conceptualizing the object structure for the object-oriented database (OODB). This database will support the website implementation.

Also, significant extensions to the scientific poster patterns will be supported by the OODB. For example, extensions such as structured layouts, short narrative discussions, images (2D and 3D), graphics, diagrams, hypermedia links (i.e., local within the database or across the internet) and full motion video.

5.3. Research Methodology

The research methodology (figure 5) begins with a clear definition of the problem to be addressed. In this study, the problem is the management of large volumes of scientific information. However, a critical part of the problem definition is an understanding of best approaches for the design of scientific information. More specifically, the problem is the design of an Information Design Pattern for the management and dissemination of ERC information. As shown in figure 5, the problem definition and information design processes begins with the ERC definition of their scientific poster patterns. Poster patterns from year-to-year will be stored in a

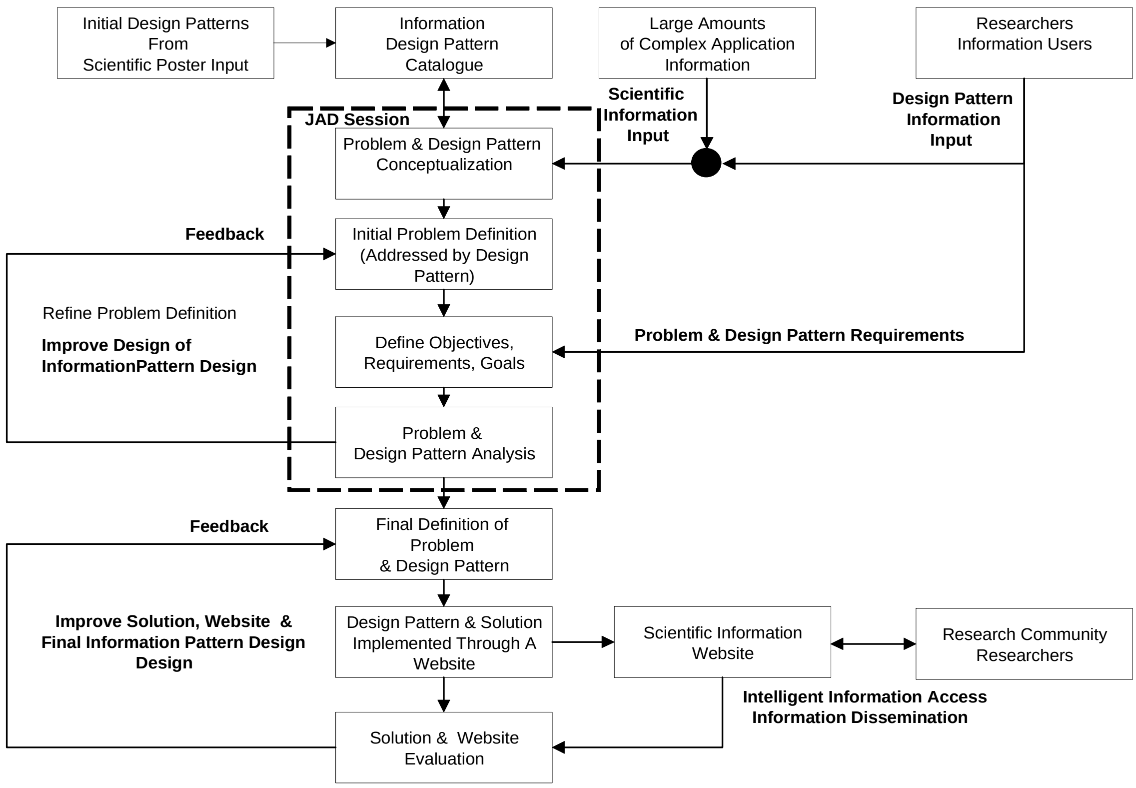

FIGURE 5: RESEARCH METHODOLOGY

catalogue in a database. The catalogue will be input to the poster development process each year. Also, as shown, the Joint Application Development (JAD)[15] process will be used to clearly define the problem being addressed as well as the information design pattern. The problem definition is modeled using object-oriented technology (i.e., using Unified Modeling Language (UML) artifacts). The model defined at problem definition time will continue to be used through the solution implementation step. The model is refined at the design and implementation stages. The JAD session brings together the researchers, application developers and any other interested stake holders (e.g., physicians, in the case of medical IDPs). After completion of the JAD session, the problem definition model and the information design pattern will be used to design the information management solution. The initial solution was delivered through a prototype website[16]. Researchers were able to interact with ERC scientific information through this prototype. In the final solution, the website will allow any researcher to access the information of any other researcher. The website will make it possible to disseminate the research information for other researchers outside the ERC.

5.4. The Scientific Information System (SIS)

Although, this software research and development effort was carried out in a research environment, it was addressed as an industrial strength[17, 18] software development effort. This means researchers addressed issues of error free code technologies and industry security standards. The software was designed to be downloadable from an NSF website and portable across all ERC's. An integral part of this research is the development of an industrial strength[13] piece of software. To develop robust industrial strength software requires a structured approach to development. The object-oriented development life cycle[12] (figure 5) provides such an approach to development. The essence of industrial strength software engineering is to introduce engineering to software development. This means setting problems in the context of known solutions and not building a product from first principles each time a new one is required. Design pattern technology[3] which uses known software solutions is being used in more software development efforts. This type of technology is moving the software development process toward a mature software engineering environment. This research focused on this type of software development.

The software to implement the SIS contains 3 subsystems (figure 6):

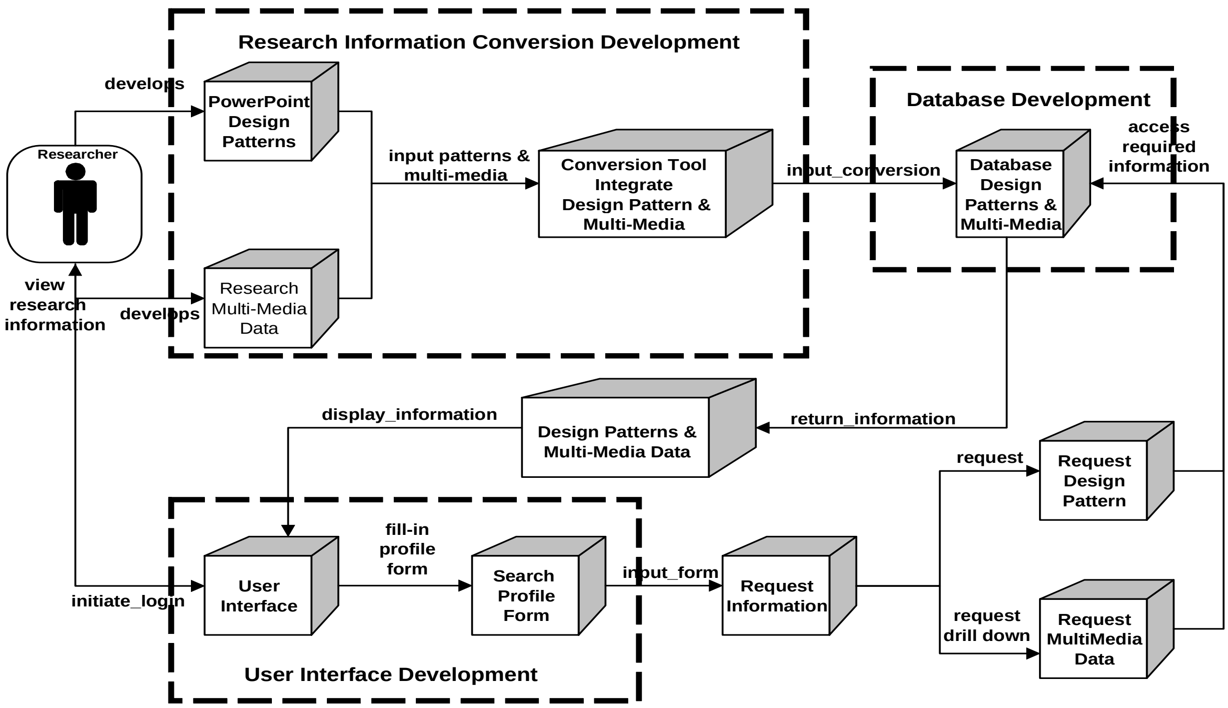

FIGURE 6: SCIENTIFIC INFORMATION SYSTEM

1. Information Design Pattern Conversion Tool: this subsystem converts the poster patterns into information design patterns with the expanded multimedia functionality as well as the object-oriented format required for the database. This subsystem reads input from any poster pattern construct and parses the objects that make-up the pattern to provide the proper structure for input to the database. Basically, this subsystem implements a poster pattern transformation process.

2. Database Management System: this subsystem will provide the interface and access to the OODB (figure 7). As shown in figure 7, it is possible to search the database using several different search schemes (figure 8). There are 3 search schemes depicted in this figure which have been prototyped in this research. One keyword search scheme is defined as being a basic search where information is searched by IDP "Title", "Problem", and "Solution". Also, shown on the diagram is an advanced search scheme where it is possible to search the database by any combination of the IDP object segments. There is a third search scheme shown, where it is possible to search for certain special multimedia information. This part of the application was implemented using an object-oriented database management system (OODBMS). The database system will archive 10 years (figure 9) of IDPs with the associated multimedia information linked through the design patterns.

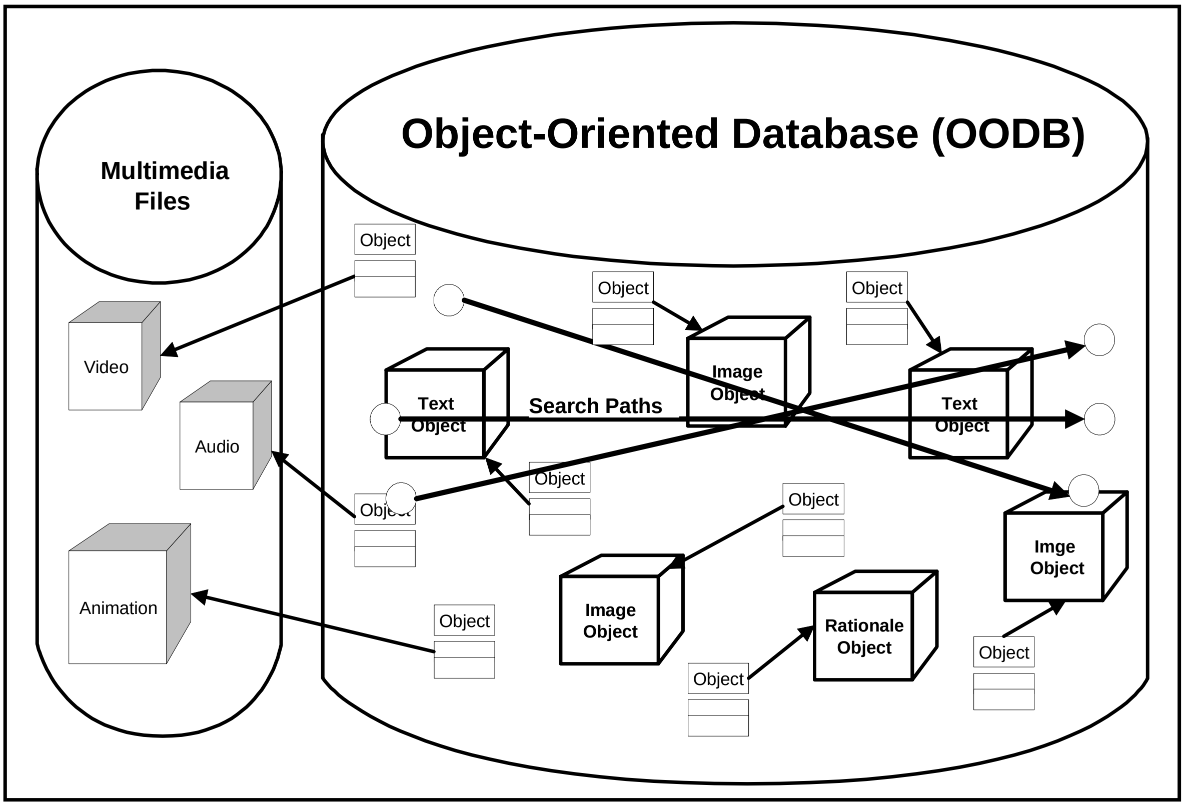

FIGURE 7: OODB FOR INFORMATION DESIGN PATTERNS & MULTIMEDIA

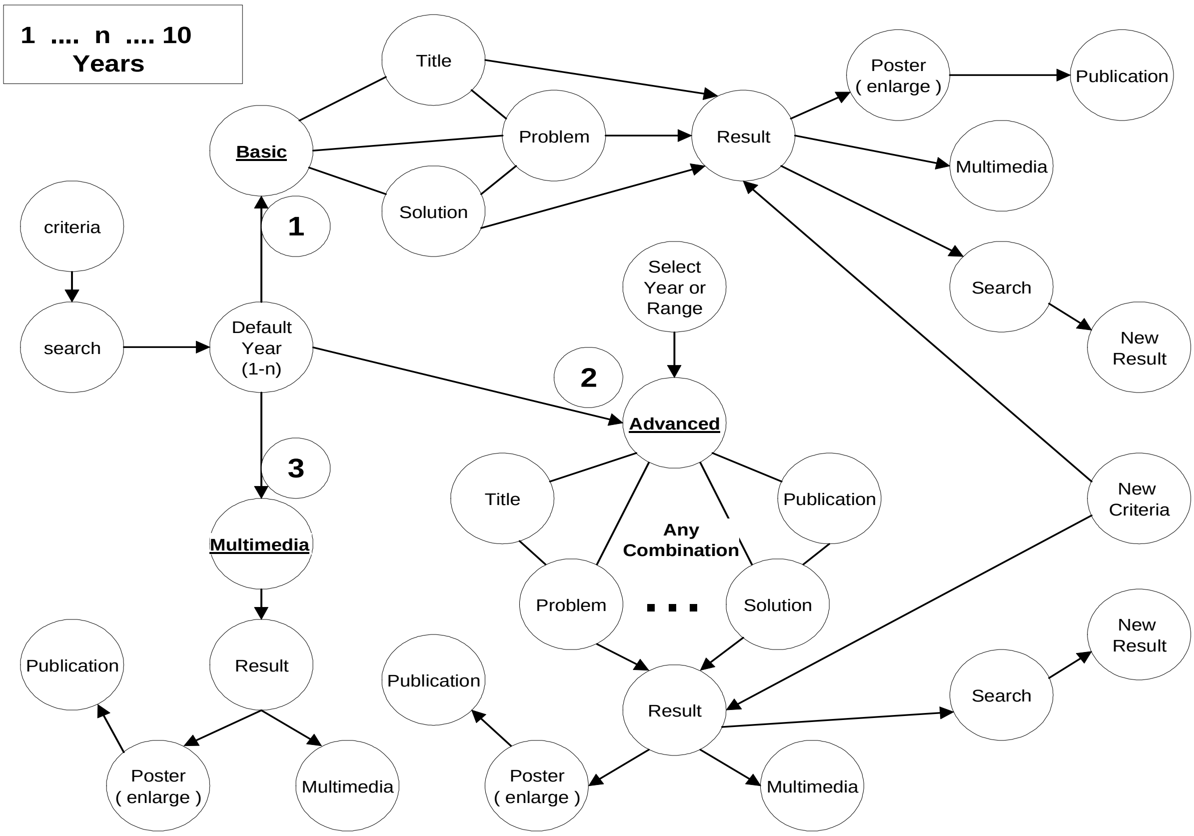

FIGURE 8: THREE KEY WORD SEARCH SCHEMES

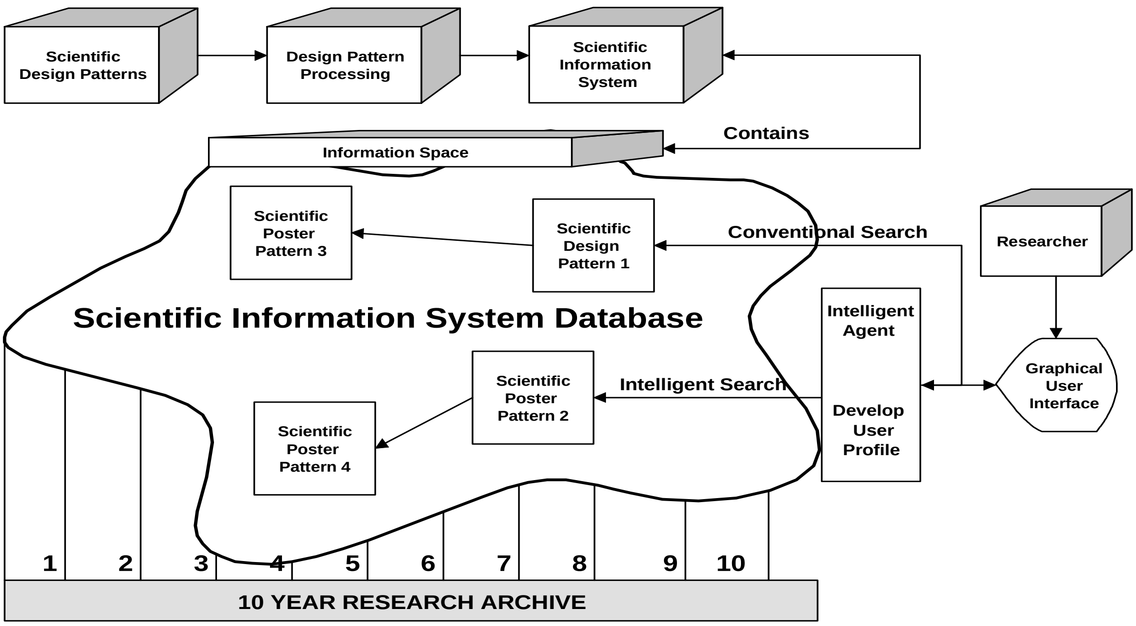

FIGURE 9: TEN YEAR SCIENTIFIC INFORMATION SYSTEM ARCHIVE

3. Graphical User Interface (GUI): this subsystem will provide the interface for researchers to access their information design patterns as well as any supporting multimedia information. The GUI will be the gateway to a wealth of scientific information and knowledge. Therefore, the GUI must implement an interface designed to support a secure and safe environment for this knowledge base.

The product delivered from this research is a website (figure 10). The website will provide researchers the capability to access and analyze the research results of other researchers in their ERC. As indicated above, the researcher will interact with the information database through the GUI. The data management subsystem will manage all database search activities. A prototype system has been developed and is being evaluated.

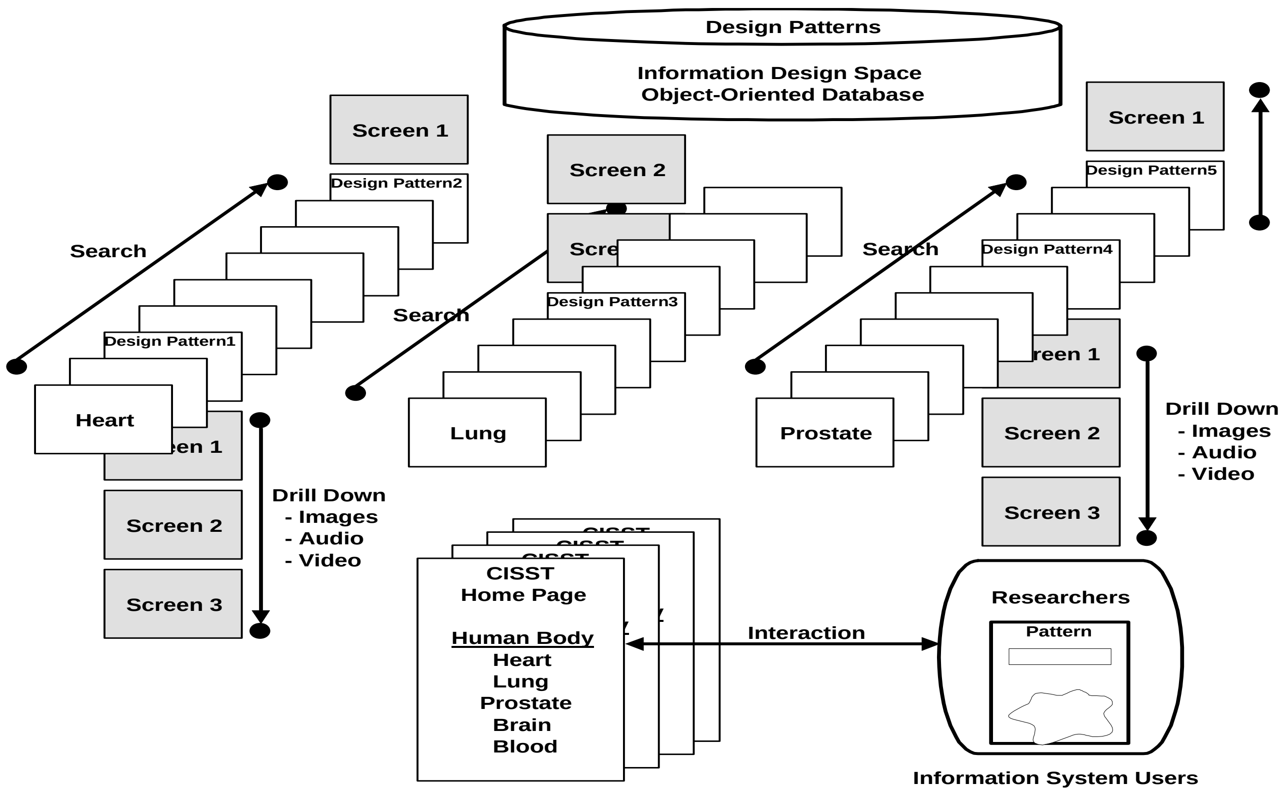

FIGURE 10: SCIENTIFIC INFORMATION SYSTEM WEBSITE

6. Findings

During this study, the research has led to a solution design that produced software which converted poster patterns to objects in an object-oriented database. Although in our initial design a Relational Database had been proposed, however, the research and use of the Object-Oriented Database has proved to be the most successful. This design also produced search schemes and a user interface for researcher interaction. A prototype of the user interface and search schemes was developed and demonstrated. This prototype was not a final implementation and was used only for user feedback and partial demonstration of its functionality. We are currently preparing a focus group for researchers that will be using the product in order to get their feedback on possible enhancements to the user interface design and database search schemes to support the next phase of this research.

Acknowledgements

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Return to Main page