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A SMIL-Based Approach for Designing Interactive Multimedia Film Players

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Keyword

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Abstract

Development of HTML-based multimedia film player applications often requires substantial scripting to synchronize layouts, user interactions, and media content. The synchronized layout has increased the complexity of developing these types of applications. The Synchronized Multimedia Integration Language (SMIL) provides built-in capabilities for synchronizing time-based multimedia; however, no empirical analysis has been conducted on the effectiveness of SMIL for the design of interactive film players. This study describes a region-based design approach for developing an interactive multimedia film player using SMIL. It provides a quantitative evaluation methodology for assessing layout design using the Layout Consistency Score (LCS) and the Screen Utilization Efficiency (SUE). The novelty of this study lies in the empirical assessment of region-based layout designs created with SMIL using the LCS and SUE as objective measures. Results of the empirical evaluation reported in this study showed that the proposed system achieved an average LCS of 0.92 (indicating a stable, consistent layout structure across different interface scenarios) and an average SUE of 0.79 (indicating an efficient use of screen space, with no visual overcrowding). The major contribution of this study is the quantitative assessment of the region-based layout designs created with SMIL using the LCS and SUE. This study provides empirical support for the premise that SMIL will reduce the complexity of developing multimedia film players and maintain high levels of layout consistency and efficient screen utilization.

1. Introduction

Due to the rapid growth of multimodal technology, demand has increased for the creation of new, interactive, and flexible media applications, specifically for digital playback systems for films. Currently, most web-based media for developing multimedia players are created using HTML with one or more additional scripting languages [1], [2] The complexity of coding required to support various media types necessitates additional layers of coding [3]. The architecture enables synchronization management between media objects, facilitates interactivity, and provides temporal control for individual media elements. The result has been limited efficiency in the development and maintenance of such systems.

The Synchronized Multimedia Integration Language (SMIL) offers an alternative approach to creating multimedia applications, providing built-in support for time-based synchronization, layout management, and user interaction [4] . SMIL is a markup language that allows developers to combine and control multimedia elements such as video, audio, text, and images through one common synchronization framework (temporal) [5] . In this way, the content's structure can be separated from its presentation logic, making it easier for developers to create complex, multi-dimensional representations of how multimedia will play out over time.

Even though the majority of previous research has focused on HTML vs. SMIL, primarily on synchronization or structure, no objective method for evaluating the quality of layout in real-world multimedia film player applications has been found. There have been many discussions of architectural differences; however, there is very little empirical evidence showing how well SMIL maintains layout and screen organization when a film is played back interactively.

To provide greater clarity about this research, two key questions have been developed: What is an appropriate design for an integrated multimedia playback architecture based on SMIL principles ? How can the layout of a SMIL-based integrated multimedia film player be measured quantitatively ?

The study presented in this paper investigates the creation of a multimedia application using the SMIL specification that enables users to easily navigate and select multiple films for their viewing experience on computer systems via an interactive interface. Each selected film will be automatically loaded into the application, along with other multimedia elements that will be in sync with it during playback. The multimedia application has been designed to work with multiple compliant SMIL players, including RealPlayer, allowing it to be used in a cross-platform environment without requiring proprietary extensions.

Although most web developers today use HTML5 extensively for web development, SMIL was chosen in this study for its native timediferent declarative timing model, built-in synchronization constructs and explicit region-based layout mechanism [6]. These features help to simplify scripting and provide a clear separation of structure from presentation logic, making SMIL ideally suited for controlled multimedia synchronization applications.

SMIL provides a more structured way to present multimedia than HTML-based implementations. The declarative nature of the SMIL specification enables the creation of an interactive multimedia presentation without requiring extensive programming skills, while also providing interactivity through built-in hyperlink and event-handling capabilities [7]. Therefore, the proposed system will demonstrate that SMIL can be used effectively in the development of interactive film player applications that are easier to design and offer better portability and temporal accuracy than those created with HTML [8].

To this point, there have been few quantitative studies of layout evaluation for SMIL multimedia systems. In particular, the use of measurable indicators (layout consistency, screen utilisation) for validating region-based SMIL design has not been systematically studied with respect to their usability in interactive film applications.

This study's primary contribution is the development of a region-based SMIL multimedia movie player and an associated quantitative framework for conducting structured evaluations of the system. The use of objective layout metrics to evaluate the system will provide empirical support for the effectiveness of SMIL for producing interactive multimedia/movie players.

1.1 Problem Statement

HTML-based multimedia video player technologies have several design complexities and limitations in synchronization accuracy and development efficiency [9] . Temporal relationships among the timelines of video, audio, subtitles, and other interactive media elements in HTML require significant additional coding, scripts, and frameworks, increasing implementation complexity and making the management, maintenance, and extension of the overall system more challenging [10].

Another major challenge is the consistency of multimedia playback behavior across multiple media players and platforms. Variations exist in timing precision, layout rendering, and how interactions are handled because HTML and its player implementations differ across browser engines. If developers do not resolve these timing variances, it will negatively impact the user experience in many applications where precise multimedia synchronization is critical [11] . Consequently, it limits their productivity and ability to rapidly prototype, develop, or modify multimedia scenarios. The more complex an application, the more difficult it is to maintain a timeline that encompasses multiple film or playlist options as well as an interactive navigation experience.

1.2 Research Objectives

The goal of this study is to develop an interactive multimedia film player application utilizing the Synchronized Multimedia Integration Language (SMIL). This application will allow users to choose and view many films that display synchronized multimedia elements, precisely in sync with each other. It will also demonstrate how SMIL can be used to easily create multimedia applications, allowing developers to leverage native time-based methods and capabilities for interacting with multimedia elements. The findings of this research will demonstrate the strengths of SMIL as a tool for developing rich multimedia content, compared to HTML-based multimedia development, specifically in terms of ease of use for developers, interactivity, and consistency over time across different media types.

2. Research Method

The methodology section outlines the procedures for planning, building, and assessing an Interactive Multimedia Film Player Application, designed using the Synchronized Multimedia Integration Language (SMIL) as its foundation. To set up and complete the project, the methodology was designed to meet the research goals by integrating the theoretical design, the application development, and performance evaluation into a single composite process. It is anticipated that, by using declarative SMIL features to ease multimedia synchronization and user interaction while remaining compatible with other current SMIL-supported media players, an appropriate collection of information will be created.

This methodology will consist of first determining the system requirements and multimedia presentation needs, then planning the System Architecture and SMIL Document Structure of the application, and finally, building and testing the application in a SMIL-compatible media player environment. The study employs several measurement techniques to assess the impact of the proposed design on interactivity, synchronization accuracy, and development simplicity. A structured methodology will ensure that the findings from this research are easily reproducible and applicable to any multimedia application development project.

The research involved assessing a sample of four test case conditions. These represented variations in the types of sync or layout conditions for how video is initially played back. The amount of temporal complexity influenced the conditions selected as examples for each test case in the content, the number of layout areas where content is located, and whether the sample included interactive presentation (navigation) elements to provide a broad range of playback conditions.

2.1 System Architecture

The application will utilize the Synchronized Multimedia Integration Language (SMIL) as its primary technology for design and architecture [12]. The primary focus of this system is to produce a modular design that allows for maximum separation of responsibilities for user interaction, synchronization across different multimedia types, and content display. Since SMIL uses a declarative format, it reduces implementation complexity while retaining interactive capabilities and compatibility across different platforms and players.

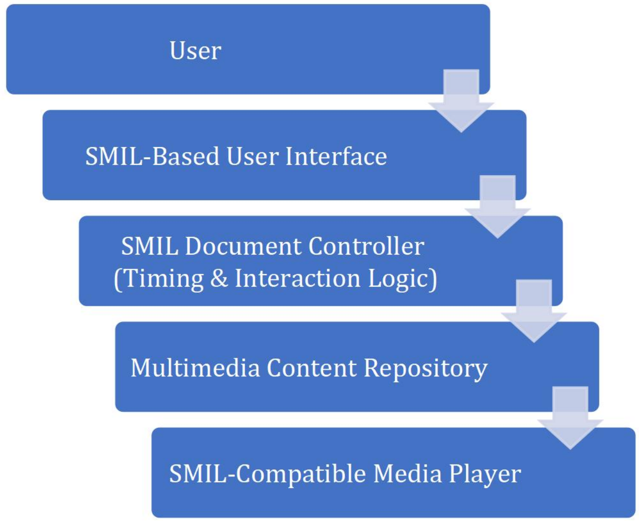

Figure 1. System Architecture of the Proposed SMIL-Based Multimedia Film Player

At the highest level, users access the application via the Graphical User Interface (GUI), which displays a list of available films. When a user selects a film or navigates to a different scene, these actions will be facilitated through SMIL hyperlink and event mechanisms. The use of these built-in functions eliminates the need for a separate scripting language and enables the creation of interaction logic to be placed directly in the SMIL document. Once the user selects the film, the SMIL Document Controller assumes control of defining the logical and temporal structure of the multimedia presentation. The SMIL Document Controller will use the sequencing and parallelism provided by the SMIL specification to organize media elements, ensuring proper synchronization among media components (video, audio, subtitles, and visual displays). The method used by the Document Controller produces a consistent timing effect throughout the film's playback.

There are many types of multimedia files, including videos, audio, and text. All the multimedia files used for the application are stored in a special location, known as a media repository. The media repository has all the multimedia files needed for the application. The SMIL document references the location of the media in the media repository. By separating the media repository from the display portion of the application, it is easier to manage and update multimedia files without affecting the rest of the application. The media player used to play and display the SMIL file is typically one that supports SMIL. An example of this type of player is RealPlayer. The media player reads the SMIL syntax from the SMIL file, executes it according to the specified timelines, and then plays back the multimedia files in accordance with the SMIL rules for displaying and synchronizing media elements. By using standard SMIL features, the application will be compatible with multiple media players that also support SMIL. The overall system architecture, along with the interaction between the SMIL file and the multimedia player's various elements, is illustrated in Figure 1.

2.2 Research Steps and Procedures

This study employs a structured, iterative method to develop, test, and evaluate an interactive media player (film) based on the Synchronized Multimedia Integration Language (SMIL). This study is structured to ensure that every step directly contributes to achieving the research goals. The overall flow of this research is illustrated in Figure 2, and the application's operation is depicted in the process flow diagram in Figure 3.

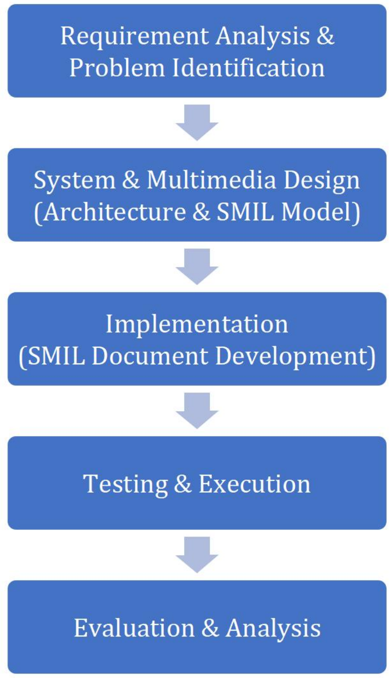

Figure 2. Research Methodology Flow

The first stage of the research involves determining what is needed for development and identifying the existing problems [13] . At this point, we will examine why traditional HTML-based film players have limitations in finding and managing synchronization and interactivity. The second stage of the research involves creating a design (architecture) for both the film player (the application) and the multimedia film design. In both stages of this research, although the needs have been specified, the system architecture determines how users interact with the application, including its presentation logic and the content of the multimedia films. At the same time, the overall structure of the SMIL documents will be designed to reflect the overall design of the user interface, as well as the playback scenarios for specific films.

Stage three of the process involves creating SMIL (Synchronized Multimedia Integration Language) documents and understanding how they interact with one another. The main SMIL document serves as the "film selection interface," while each SMIL document determines how those films will play back. At this stage, all components have been integrated to form a project (video, audio, text) using their external references. Furthermore, all interactive components (how users interact with the movie) utilize hyperlinks and events without requiring a single line of external programming language code.

Stage four involves running and testing the application that was built in Stage Three. To confirm that everything functions correctly, a compatible player is used to run the application. The four areas of testing encompass proper interpretation of SMIL documents, synchronization of multimedia elements, reliable user interactions during playback, and execution of the system according to the process diagram in Figure 3.

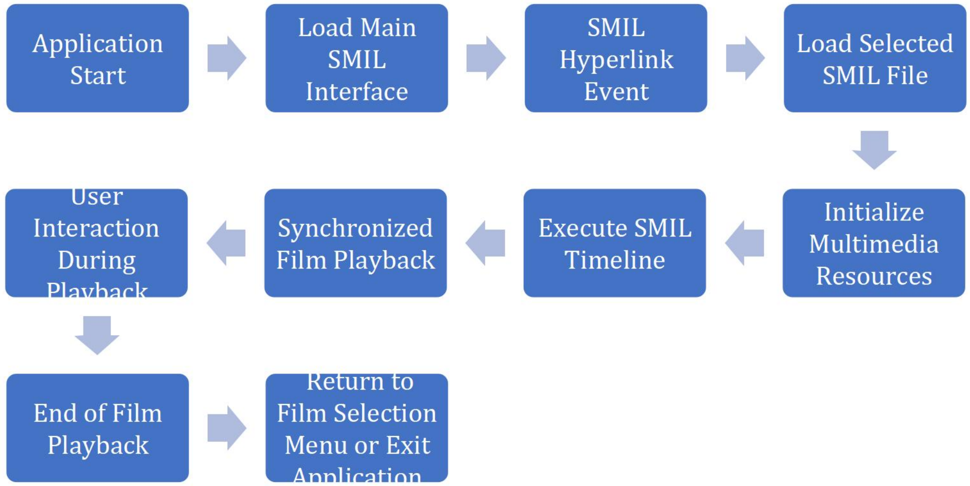

Figure 3. Process Flow of the Proposed SMIL-Based Multimedia Film Player

2.3 Measurement Techniques

In this research, quantitative measurement techniques are employed to evaluate the layout quality of a SMIL-based multimedia film player application. Two layout-related measurements were examined in this evaluation: a Layout Consistency Score (LCS) that evaluates the application of multimedia element placement across the application, and a Screen Utilization Efficiency (SUE) score. Both the LCS and SUE scores are used to evaluate how well SMIL manages the spatial layout of multimedia elements across different films or clips during playback. To maintain analytical focus and ensure alignment with the study's defined scope, only two measures were used: LCS (Layout Consistency Score) and SUE (Screen Utilization Efficiency), to evaluate structural layout consistency and screen space efficiency in a SMIL (Synchronized Multimedia Integration Language)- based system. These two measures reflect the core purposes of this research, and provide enough data to analyse layout effectiveness.

The LCS score is calculated based on the stability, consistency, and uniformity of multimedia element placement in the application [14] . The LCS assesses how consistently video, text, and/or other visual components are positioned and sized according to their definitions across all scenes and/or films. Therefore, the calculation of the LCS is based upon equation (1).

$$LCS = 1 - \frac{1}{n}\sum_{i-1}^{n}\frac{|P_i - P_{ref}|}{P_{ref}} \quad (1)$$

Where:
LCS = Layout consistecy score
P_i = position or size of element in scene i
P_{ref} = reference position or size
n = number of scenes

The higher the LCS value (greater than 0 and/or very close to 1), the greater the consistency and stability of layout management via SMIL Regions. The Screen Utilization Efficiency (SUE) indicates how efficiently the multimedia objects on-screen fill the available display area while playing [15]. The SUE is the ratio of active multimedia components occupying a section of the screen to the total available display area for multimedia objects. Calculation of the SUE is shown in equation (2).

$$SUE = \frac{A_{used}}{A_{screen}} \quad (2)$$

Where:
SUE = Screen Utilization Efficiency
A_{used} = Total area occupied by visible multimedia
A_{screen} = Total display area

The ideal SUE score strikes a balance between layout elements, avoiding both excessive empty space and overcrowding, also enabling easy viewing and a better overall experience. LCS and SUE also work together to provide an objective assessment of layout quality, as they illustrate how the SMIL standard allows for the optimal placement of multimedia elements within an interactive film player application in a standardised manner.

Measurement validity has been achieved through the specification of clearly defined, directly related structural and spatial evaluation criteria, each with a specific method of evaluation. Measurement errors may occur in an evaluation if the region's configuration varies, the screen's resolution settings change, or there are discrepancies during calculations; this will be mitigated by using a defined, consistent, standardised set of evaluation criteria for each type of evaluation performed. Reliability of the layout evaluation is achieved by using the same measurement procedures and configuration parameters for each testing case; this ensures consistent, comparable, and replicable results across all cases.

Several limitations exist for this research project. The study analyzed only four films, rather than a wider range of multimedia formats. User-centered usability testing and performance benchmarking were not part of the evaluation process; therefore, there was no assessment of the user experience or computational throughput efficiency. The lab tested each experiment multiple times to ensure consistent results; however, the findings from this study were limited to evaluating the structural layout within the scope and parameters of the experiments.

3. Result and Discussions

The results will be examined relative to the quality of the graphical layout by presenting our findings in terms of Graphical Layout Consistency Score (GLCS) and Graphics User Interface Screen Utilization Efficiency (GUI SUE) as well as how well SMIL supports a consistent and efficient graphical layout when developing multimedia applications with multiple playback configurations through SMIL. To facilitate understanding of the results, the results will be organized as follows:

- An image of the completed SMIL-based film player application showing its graphical appearance;
- Tabular summaries of quantitative results derived from calculations made using GLCS and SUE;
- Interpretive analysis of the results; and
- Evaluation of the results against the design aims and advantages of using SMIL to create multimedia film players.

The screenshots demonstrate the implementation of a SMIL (Synchronization Markup Language)-based multimedia player application running in RealPlayer and give the reader a good idea of how the application is laid out, what its user interface consists of, and how the user will interact with it. The first screenshot shows what the user sees when they launch the application (see Figure 4).

This screen is usually where the user is directed to select the movie they want to watch. The studio title is prominently displayed at the top of this screen, followed by four panels showing the available movies, each laid out in an orderly, consistent format. Each of the four panels allows the user to select the movie they wish to view from the list, while a small piece of descriptive text at the bottom of the screen provides additional details and/or instructions for proceeding. This research was conducted in a controlled, experimental environment featuring four films presented in a single viewing window with a steady, consistent layout. Repeating each trial multiple times at the same experimental configuration increases the repeatability and reliability of the structural layout conclusion. Even though the research does not include user-based usability tests or performance benchmarks, the repeated testing enhances the ability to replicate results within the scope of the research.

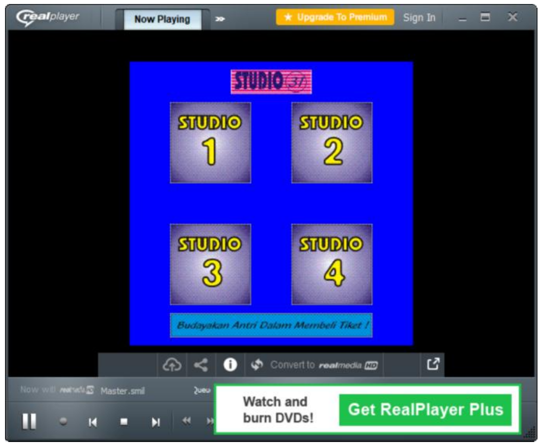

Figure 4. Initial Interface of the SMIL-Based Multimedia Film Player in RealPlayer

The extraction of the second screenshot is shown in Figure 5. In this second screenshot, after selecting a film from the list, it plays in the top half of the window, giving the user the largest area to view it. The bottom-right corner of the layout includes a back button that lets the user pause the film and return to the main selection screen. As this example illustrates, SMIL can create a uniform navigation method for accessing films through a consistent layout of the film player. Both figures illustrate how SMIL can be used to develop a multifunctional multimedia film player that offers an integrated approach to organizing and presenting information. Therefore, both illustrations highlight SMIL's capabilities to function effectively within the framework of a multimedia player such as RealPlayer.

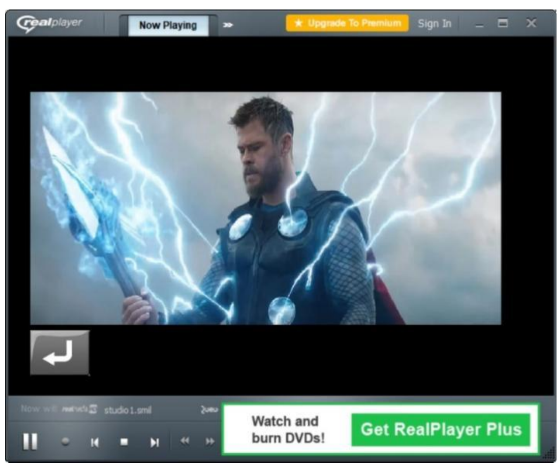

Figure 5. Film Playback Interface with Navigation Control in RealPlayer

Table 1 presents results showing that the proposed SMIL-based implementation of multimedia film players achieves high layout consistency across various interfaces. The LCS values for both the film playback and the main user interface were greater than 0.90. The average score across all samples was 0.92, indicating that the spatial positions and sizes of multimedia elements are consistently maintained when moving from the main menu to the film playback interface. The use of SMIL layout regions provides an adequate mechanism for establishing stable visual frameworks, thereby significantly reducing unintended movement of interface elements during interaction with and playback of a film.

The efficiency with which screens are utilized is reflected in a SUE range of 0.72 to 0.82, with an average of 0.79. The lower SUE value for the initial interface is primarily due to the space allocated to navigation buttons and textual descriptions, which improve overall visual clarity. Subsequently, while films are actively playing, SUE values are considerably higher, as the majority of the screen is occupied by the video content, thereby allowing better use of the remaining display area without cluttering the appearance.

An overall score of 0.92 means that the layout is very similar across all playbacks; there are only slight differences in position or proportion between any two scenes. This means that there is excellent structural consistency between regions. These types of differences will likely occur due to slight pixel-level differences caused by scaling when display resolution changes or by using an approximate mathematical method to calculate area, but they should be minor under similar conditions. A surrounding area score of 0.79 indicates that 79% of the current screen area is being used effectively, suggesting reasonable space efficiency. However, this is not an absolute measure of whether space is being wasted, since there are times when some areas may be left in their present condition to maintain visual sight and reduce cognitive load. Balancing high layout consistency with the effective use of screen area involves finding an equilibrium between compactly allocating regions while allowing comfortable navigation and reading. If there were an excessive amount of screen area, the interface elements would be placed too closely together visually.

Results from a comparative analysis of high and balanced LCS values across all cases indicate that the system proposed in this study has demonstrated consistency and efficiency in layout across various usage situations. Therefore, this study demonstrates the success of implementing a region-based layout system via SMIL. Moreover, this research's results validate that SMIL's region-based layout and declarative design approach support the creation of visually structured and stable multimedia presentations. The results from LCS and SUE confirm that SMIL successfully establishes reliable guidelines for creating interactive multimedia film player applications that maintain long-term layout quality and efficiently utilize available screen space.

This architectural embodiment indicates a degree of scalability of the document structure because the design allows the incorporation of more media elements and/or navigation regions through modular region and timing definitions, without fundamentally changing the underlying unity of the document structure. Aside from this example, the current relevance of SMIL as an established standard for contemporary use on the web may no longer be the dominant architecture, but the declarative synchronization model and precise timing coordination defined by the SMIL specification do remain of particular conceptual value for controlled presentations of multimedia, educational media system applications, and research-based prototype applications, where much of the overall structure is dependant on accomplishing structured temporal coordination.

From a research perspective, the results obtained in this study are consistent with recent studies in multimedia interface design and interactive media systems. Recent research indicates that screen layout and interface organization significantly influence usability, task performance, and visual search efficiency in digital systems. A study by Chen et al. demonstrated that structured screen layouts improve user interaction performance and subjective usability evaluations because users can process visual elements more efficiently when interface regions are clearly organized. These findings support the interpretation of the SUE results in this study, where the allocation of screen regions for navigation and content helps maintain visual clarity and usability during multimedia playback[16], [17].

Similarly, recent research on interface design and usability guidelines highlights that consistent layout structures help users predict the position of interface elements and reduce interaction errors, which ultimately improves user experience in digital systems. Diehl et al. emphasized that well-structured interface design plays a crucial role in improving usability and ensuring that users can easily understand and interact with system components. This aligns with the high Layout Consistency Score (LCS = 0.92) obtained in this study, indicating that the spatial arrangement of multimedia regions remains stable across different playback scenarios[18], [19].

Furthermore, recent studies on multimedia technologies emphasize that well-designed multimedia systems integrate multiple forms of media—such as text, audio, video, and interactive elements—in a structured manner to enhance user engagement and information processing. Research on multimedia systems in educational and interactive environments shows that structured multimedia presentations can improve user engagement and system usability when spatial and temporal coordination of media elements is carefully designed[20].

In addition, recent research on multimedia authoring tools highlights that declarative multimedia models such as SMIL remain relevant for structured multimedia presentation design, particularly in systems that require precise control of spatial layout and temporal synchronization between media components. Studies on multimedia authoring attributes emphasize that the integration of editing, service, and performance attributes plays an important role in ensuring the reliability and scalability of multimedia presentation systems[21].

Taken together, these studies support the findings of the present research that structured region-based layout and consistent spatial organization are critical factors in maintaining interface stability and usability in multimedia applications. The combination of high layout consistency (LCS) and efficient screen utilization (SUE) in this study indicates that the proposed SMIL-based architecture provides a balanced framework for organizing multimedia elements while maintaining visual clarity and interaction efficiency. Consequently, although modern multimedia systems increasingly adopt HTML5-based architectures, the declarative synchronization model and region-based layout concept provided by SMIL still offer valuable design principles for building structured multimedia applications, particularly in educational media systems, research prototypes, and controlled multimedia presentation environments.

Tabel 1. LCS andSUE Measurement Results

Interface Scenario	LCS Value	SUE Value
Initial Interface (Main Menu)	0.94	0.72
Film Playback – Film 1	0.92	0.81
Film Playback – Film 2	0.93	0.80
Film Playback – Film 3	0.91	0.79
Film Playback – Film 4	0.92	0.82
Average	0.92	0.79

A previous study using the Manim (Mathematical Animation Engine) reported an average Layout Consistency Score (LCS) of 0.77, indicating moderate layout consistency [22] . In comparison, this study produced an average LCS of 0.92. Therefore, the higher score indicates that using SMIL as the basis for the proposed method resulted in better structural layout consistency and more stable region alignment across different scenes than did the previous method.

4. Conclusions and Future Works

The purpose of this study is to create and evaluate an interactive multimedia film player using the SMIL (Synchronized Multimedia Integration Language) format. By allowing users to declare multimedia content attributes in SMIL, this app lets them select a film and play the content synchronously with it, eliminating some of the design complexity associated with developing multimedia applications. A SMIL-compliant media player was used to successfully build and operate the proposed system, demonstrating that SMIL is a viable option for building multimedia film players. Based on the findings of this evaluation, the system has been determined to provide consistently high Layout Quality across all cases tested. The average Layout Consistency per case was 0.92 (the highest possible value is 1.00). The average Screen Utilization Efficiency across all tested cases was 0.79. Based on these averages, SMIL has been effective in providing an organized and coherent multimedia presentation through its region-based layouts and declarative structure. Therefore, the use of the SMIL format for designing multimedia film players is advantageous compared to traditional HTML-based designs as SMIL provides for greater design simplicity, greater layout consistency, and greater interactivity.

There are several limitations to this research. This evaluation utilised only four films in a controlled setting, assessing only their structural layout performance. There was no user-based usability testing or computational performance benchmarking done. While multiple trials were conducted to validate the results, the applicability of these findings will be limited to the layout of films viewed in this manner under the stipulated predefined conditions.

This study contributes to the academic literature by presenting an established, measurable method of assessing multimedia layout consistency in SMIL-based environments. On the practical side, the study's results show that a declarative region-based design can have high levels of structural stability (regional consistency).

Future research should include user-centered usability testing, performance comparisons between SMIL and other HTML5-based multimedia players, extensive cross-platform compatibility testing, and an in-depth study of dynamic content integration at different playback rates. These extensions will help expand the validity and provide additional knowledge about the practical application of SMIL in today's multimedia system development.

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