A layered architectural model for music: Malaysian music on the World Wide Web

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The design and development of a layered Web architecture for Malaysian music can be applied as a model of Web architecture for music education, specifically for the introduction of the music of a particular country or region. The model is designed and developed in two phases: the building of the subject architecture and the design and development of the application architecture. The complete Web architecture is analysed and tested to determine its suitability for delivery of music-related content. Research findings indicate that the Web architecture is reliable, efficient and suitable for its purpose. The classification scheme proposed is found to provide a firm foundation for the building of the Web architecture. In conclusion, the prototype model provides a suitable extensible platform for the delivery of music content, which may be packaged for the purpose of education.

1. INTRODUCTION

The results of research on Malaysian music (Ang 1997a) are used as the primary source of content to be presented through the Web application. The development of an effective interactive multimedia computer-assisted instruction system should be based on the content to be communicated to the learners (Tu and Pai 1996). The design and development of the Web architecture for Malaysian music is therefore dependent on a well-structured and logical subject architecture, reinforcing the need for a comprehensive classification system for Malaysian music. The classification system (Ang 1997a) provides a systematic basis for the categorisation and organisation of information on Malaysian music (the subject architecture), which is used to develop the application architecture.

The Web architecture designed is a two-layer one, comprising the visible or apparent layer, determined by the subject architecture, and the file storage structure or underlying layer, i.e. the application architecture. The work consists of two primary sections: research on Malaysian music and the building of the subject architecture, and the prototype application architecture development.

Many World Wide Web (WWW) sites exhibit poor implementation, being merely Hypertext Markup Language (HTML) versions of printed information. Many online companies have sprung up specifically to address the need for structured Web architectures, providing (chargeable) site design and restructuring services. The MUSE CD-ROM (1997), which contains the RILM abstracts of music literature and the Library of Congress music catalogue, reveals that as yet no research has been published on the subject of Web architectures for music. The design and development of the two-layered Web architecture for Malaysian music can therefore be applied as a model of Web architecture for music, specifically for the introduction of the music of a particular country or region.

The subject architecture is reflected in the hierarchy of the Web pages contained in the application. The application architecture reflects the subject architecture, but does not mirror it exactly. Design principles adopted include hardware independence, portability, modularity, maintainability, extensibility, distributed architecture, open system, and efficiency of coding.

2. SYSTEM DEVELOPMENT PROCEDURE

The system development procedure (Ang, Ramani, Tee and Abu Talib 1998a) comprises two main sections: the general procedure in developing a multimedia system for education, and the procedure for developing the content to be presented. The right side of figure 1 focuses on providing the content and building the subject architecture for the Web application on Malaysian music. The review of literature on Malaysian music provides a foundation from where a systematic classification method for Malaysian music is proposed. This classification method provides a framework for the subject architecture. The interface design is developed, based on the application architecture, and the media to be communicated is decided. Data is collected and archived. The

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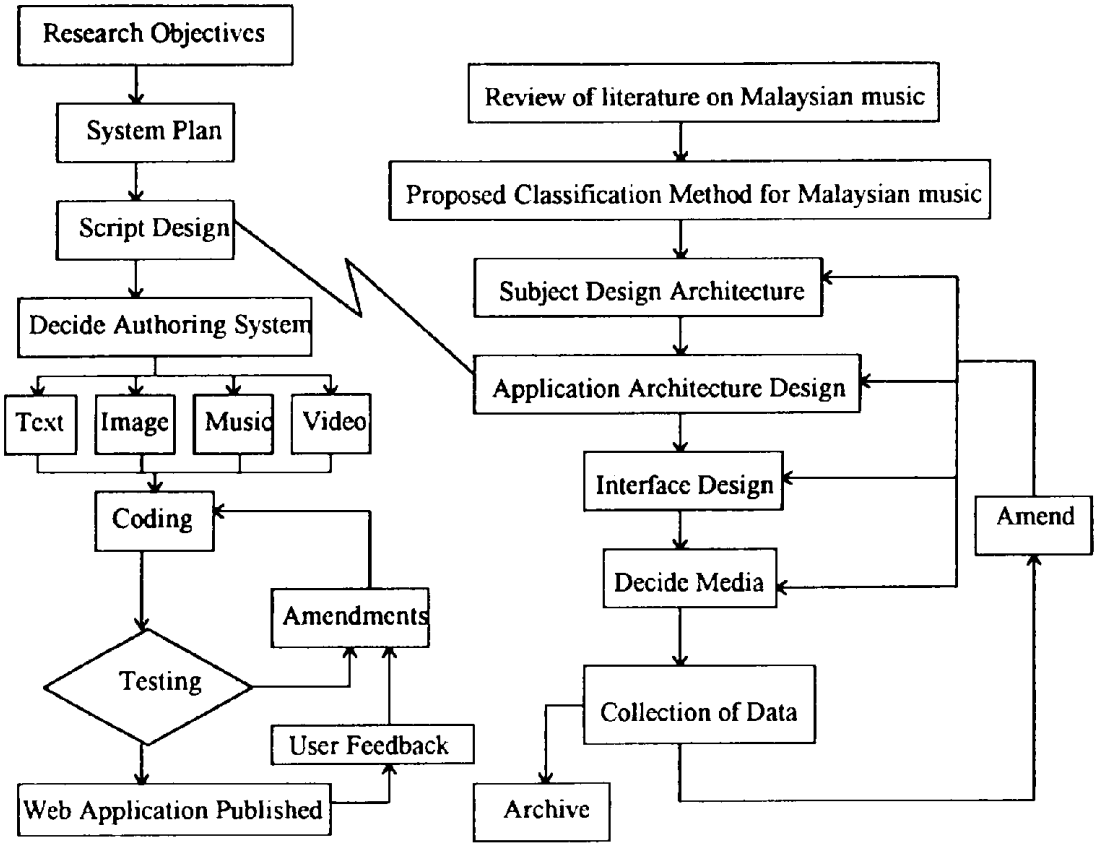

Figure 1. System development procedure.

need to amend the subject architecture, application architecture, interface design or media used may arise as a consequence of data gathered, changing interface requirements or new technologies, as illustrated by the iterative loop at the right side of the flowchart. This allows for continual updating of data included.

The left side of figure 1 focuses on the application development procedure itself. General research objectives are first clearly defined and a system architecture is proposed. Script design follows, based on the subject structure design and application architecture. The authouring system to be used is decided and data processing follows. Coding of the actual Web application pages then takes place, including testing. Pages are then published on the WWW. Feedback is obtained from visitors to the Web site via e-mail and through the signing of the site guestbook. Suggestions for improvement are taken into consideration and implemented where feasible. Coding is modified with this purpose. The iterative loop on the left of figure 1 illustrates this continual upgradation and enhancement of the application. The classification method for Malaysian music is considered further.

2.1. The classification method for Malaysian music

It may be convenient to start by describing the musics unique to the various ethnic communities, as most material published at present is available in this format. However, to do so would be to further emphasise the artificial division of Malaysian society created by former colonialist policies. A better way of classifying and categorising Malaysian music may be seen as proposed in figure 2 (Ang 1997a).

Robert Redfield (1973) in his work on culture theory defined the 'great tradition' of the reflective few as one which is consciously cultivated, refined and handed down in a formal learning situation. The 'little tradition' of the largely unreflective many is defined as one which keeps itself going, is taken for granted and is not put under much scrutiny or deliberate refinement and improvement. The initial step in designing a well-structured Web architecture involves defining a first level of data categorisation (table 1). For this purpose, while it should be understood that Redfield's definition is by no means clear cut and that many grey areas exist, music commonly known as 'traditional' or belonging to the little tradition as described by Redfield will be termed *folk music*, while music which is or has been consciously developed and cultivated deliberately will be classified as belonging to the great tradition. These definitions are adopted for our purposes from Redfield's culture theory. Great tradition music is further subdivided into three main categories: *contemporary art music*, which

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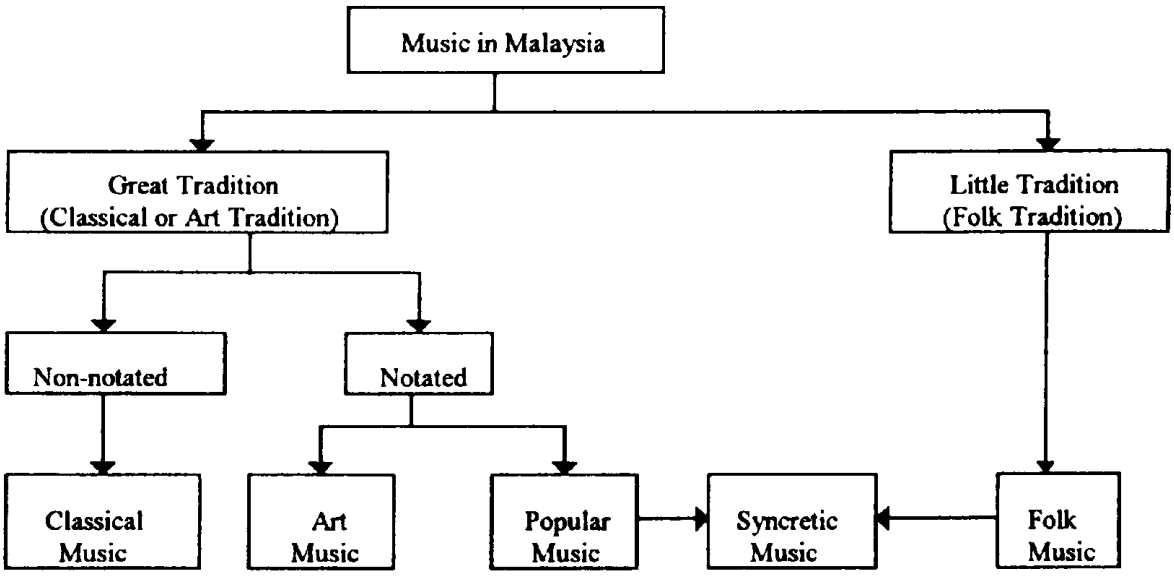

Figure 2. Diagrammatic representation of types of music in Malaysia.

encompasses notationally transmitted music composed by specific individuals as an expression of their artistic creativity, *classical music*, which is defined here as traditional classical music developed as palace traditions such as gamelan Melayu and Nobat, consciously cultivated as a high art form but not primarily notationally transmitted, and *popular music*. This broad classification method is used by Matusky and Tan (1997), but is not defined rigorously or in greater detail.

The categories are proposed as a guide to organising the database of musical information for systematic data classification, ease of retrieval, and to help the layman to gain a broad overview of the types of music in the country. In addition to these categories, folk music may be further subdivided into various overlapping subcategories, represented by a flat table in first normal form[1] (Date 1990) (table 2). 'Religious' and 'ritual' music are distinguished under the main headings 'spiritual' and 'individual', respectively. 'Religious' music is defined as music which is used in conjunction with religious worship or religious services, while 'ritual' music is defined as that which is used in conjunction with secular or social rituals such as Malay weddings. Music listed under the category 'non-religious' and 'social' includes music which is used in a social context, though not in a ritualistic sense. Examples of this sort of music include children's songs. 'Festive' music is defined as music which is associated with, and usually only performed during, specific festivals which occur at specific times of year, such as Hari Maulud Nabi, Chinese New Year and Deepavali. 'Independent song' as opposed to 'dance' and 'theatre' music is defined as any music, including vocal song, which is sung or performed independently of dance or drama. Any specific song or piece of folk music may be described as belonging to any or all of the subcategories listed (i.e. the subcategories are not mutually exclusive): *spiritual*, *individual*, *community* or *function*. For example, a religious song which is sung only in a social context, though not part of any set ritual, during a specific festival each year might be categorised as 'religious', 'social', 'festive' and 'independent song'. Figure 3 shows a

Table 1. First level of categorisation.

	Great tradition	Little tradition
Non-notated or mainly non-notated	Classical music	Folk music
Notated	1. Contemporary art music 2. Popular music	—

[1] A table in first normal form satisfies the property that at every row and column position within the table there is always exactly one data value, never a set of multiple values.

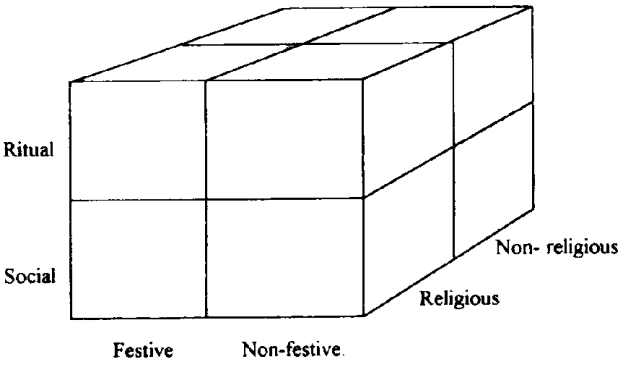

Figure 3. Conceptual view of overlapping folk music subcategories.

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conceptual view of the first three of these overlapping

Table 2. Subcategories of folk music in Malaysia in first normal form.

Spiritual	
Music type	Subcategory
Folk	Religious
Folk	Nonreligious
Individual	
Music type	Subcategory
Folk	Ritual
Folk	Social
Community	
Music type	Subcategory
Folk	Festive
Folk	Nonfestive
Function	
Music type	Subcategory
Folk	Music for dance
Folk	Music for theatre
Folk	Independent song

subcategories (table 2), all of which include the functional subcategories of music for dance or theatre or independent songs (Ang 1997a). The reason for the levels of subcategorisation is to provide for alternative search criteria. These search terms are included in the HTML meta name tags. Documents containing these terms may be located using a keyword search.

Further discussion on Malaysian music is approached from the point of view of the above representation, with data gathering being carried out systematically according to the schema described. The data collected is organised for the Web application into a suitable architecture, based on the proposed classification method.

2.2. Data collection methodology

Data[2] on Malaysian music is compiled from several sources. The data collection methodology described in the following paragraphs is illustrated in figure 4 (Ang and Ramani 1998).

Where scholarly publications on the topic are available, information from these sources is used. General publications are referenced on topics which are not covered by scholarly publications. In addition to this, general references are also cited to indicate the type of information available to the general public on music in Malaysia, in view of the fact that one of the aims of the current work is to develop a source of general reference.

It is found that many types of music practised by various groups in Malaysia are not yet referenced by

[2] *Data* as used here includes text-based information, pictures and photographs, music scores, audio and video recordings.

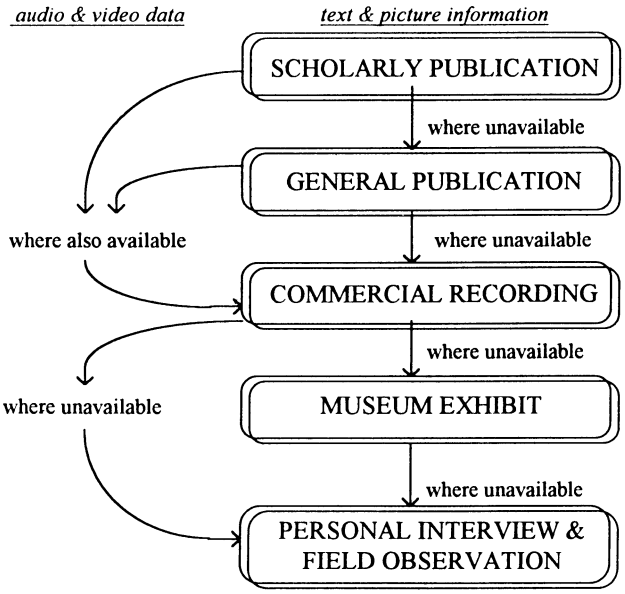

Figure 4. Data collection methodology.

any publications at all, either scholarly or general, and that many more types are mentioned only in passing. Where commercial recordings of such music were available, clips of these have been included in the multimedia application. Such clips are also included to illustrate those topics which were covered by the other existing publications.

Information on certain types of music not covered in currently available publications is available from museum exhibits in various museums around the country. Several of these museums were visited to obtain such material.

Types of musics not covered by any of the other means above but nonetheless commonly known among various Malaysian communities are researched and documented through personal interviews and field observations. Field observations include audio as well as video recordings (where permitted), photographs, collection of music scores, and other related information including noncommercial audio and video recordings. A field study questionnaire was designed to aid data gathering. Data gathered is organised according to the classification method in figure 2; the complete (expanded) version is shown in a different way in figure 5. The Web development methodology is discussed further.

3. WEB DEVELOPMENT METHODOLOGY

The Web development methodology is adopted from December's (1996, 1997) methodology for developing WWW-based hypermedia works. These principles are applied to the design of the Malaysian music Web site, as discussed below.

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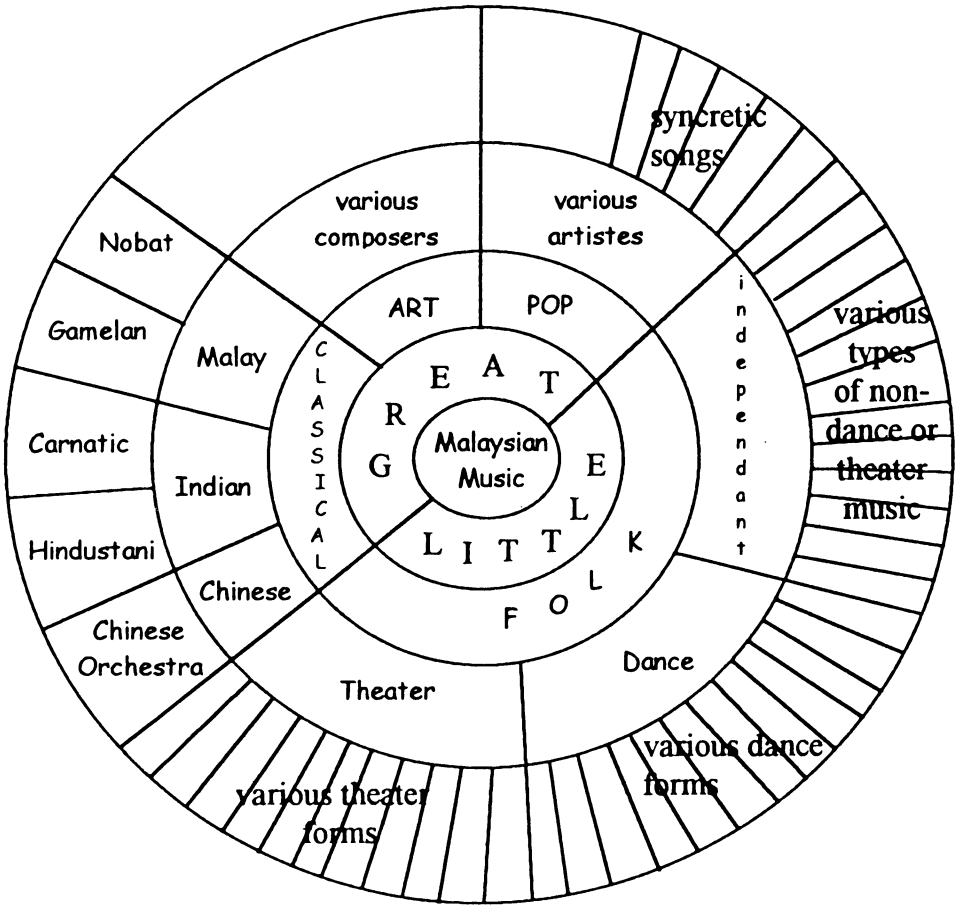

Figure 5. Summary overview of the classification scheme, including the types of music in Malaysia.

3.1. The six key elements

3.1.1. *Audience information*

The target audience for the Web application on Malaysian music is anyone who wants a general introduction to the topic of Malaysian music. The audience is expected to possess fundamental knowledge on how to use the computer and the WWW. The audience may or may not have knowledge of music fundamentals, including the ability to read notation. Most of the target audience is expected to have only limited knowledge of Malaysian music, or even a misconception as to what constitutes Malaysian music, due to the lack of currently available general introductory information on the subject. For most of the ultimate target audience (the Malaysian public), English is a second language. To reach a wider (international) audience, English is the chosen medium of communication for the Web application. The fact that many of the target audience are not native English speakers is taken into consideration when writing the text to be contained within the HTML pages, to be read by the users.

3.1.2. *Purpose statement*

The Web site aims to provide a comprehensive general introduction to all the types of music found and practised in Malaysia.

3.1.3. *Objectives list*

To achieve the goals of the purpose statement above, the specific objectives that the Web application on Malaysian music should accomplish are listed here:

(1) As far as possible, all the types (genres) of music found in Malaysia should be represented.
(2) The music of all the different ethnic groups in Malaysia should be represented.
(3) Users should be able to answer the question, 'What is Malaysian music and what does it comprise of?' after going through this Web site.
(4) An online archive of information and multimedia files on Malaysian music should be easily available to the public.

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3.1.4. Domain information

The domain information is the content on Malaysian music. This includes all the data collected on Malaysian music, as described in the sections on data collection and organisation earlier in this paper. This information is what is used to build the subject architecture, or the visible layer of the two-layered Web architecture.

3.1.5. Web site specification

The specification statement details what pieces of domain information are to be presented as well as any technical or policy limitations on that presentation. The technical specifications, such as the exact content of the information to be presented and which data formats are to be used, are discussed in detail in Ang and Ramani (1998). Other design constraints, including legal and ethical aspects of the information to be presented, are discussed in Ang, Ramani, Tee and Abu Talib (1998b).

3.1.6. Web site presentation

The presentation is the result of design and implementation processes that work within the Web site's specification, essentially the sum total of all the HTML files plus associated multimedia files or other software (CGI, Java, or other) to support the Web site. It also includes provision for backups and protection of the physical media, hardware and electric resources that make the Web site accessible to its users, and planning and provision for appropriate network, software and hardware security measures to protect the Web site's infrastructure (December 1996). The presentation, essentially the application architecture, is discussed further later on in this paper.

3.2. The six ongoing processes

3.2.1. *Planning*

The planning process begins with the identification of the six key elements, which has been carried out in the preceding section. It also includes identifying the skills and resources needed for developing, constructing, deploying and operating the Web site.

To develop the Web site, the application developer needs to possess or acquire the following skills: advanced HTML, digital audio data processing and editing, digital video editing, MIDI sequencing and music arrangement, graphic processing and editing, JavaScript basic programming, basic PERL programming for CGI scripting, and layout and design of Web-based documents. Additional skills which are required for the effective implementation of the application are Web server administration and basic UNIX.

3.2.2. Analysis

The objective of the analysis is to weigh alternatives and gather information to help with the other processes of Web site development, including planning, design, implementation, promotion and innovation. This involves the three elements described below.

3.2.2.1. *The technical analysis*. This is a check of the technical implementation of the Web site with validation tools. It tests whether or not the Web site's presentation is functionally operational and consistent with its specifications and design, as well as current HTML practices and syntax.

3.2.2.2. *The usability analysis*. This checks how the site is being accessed, both in terms of its own files and in terms of outside links into it; whether or not the Web site's user interface is usable and effective; and whether or not the Web site is accomplishing its stated purpose and meeting its objectives.

3.2.2.3. *The content analysis*. This evaluates the consistency and verifies the correctness of the information content of the domain information. It checks that the domain information content is correct, relevant and complete, and is accomplishing objectives that meet the needs of the users. This process is carried out continuously, from the moment of data gathering, through the process of organising the data collected and proposing the classification method for Malaysian music, during the organisation of the subject architecture and after the implementation of the Web site (through user feedback from experts in the field of Malaysian music).

3.2.3. Design

The design process involves creating a consistent look and feel for the Web site, separating information into manageable page-sized chunks, providing cues for the user about the Web site's information structure and contents, context and navigation, and using links to connect pages along the routes of use and user thinking. The details of this process are contained in section 4.1 below, with further details available in Ang and Ramani (1998).

3.2.4. Implementation

The implementation is the process of building the Web site according to its design. This process involves the creation of an extendible directory and

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file structure to manage the Web site's files and/or software components (CGI or Java programs – the building of the application architecture, or underlying layer of the two-layer Web architecture. This process is described in section 4.2 below, with further details available in Ang and Ramani (1998).

3.2.5. Promotion

Promotion is the process of handling all the public relations issues of a Web site, including making the existence of a Web site known to online communities through publicity. Details are discussed in section 5.2 below.

3.2.6. Innovation

The final process in the Web site design methodology adopted (December 1996, 1997) is innovation, which is the process of continuously improving the usability and quality of the Web site to meet and exceed user expectations. This involves finding creative or unique way to improve the elements of the Web site or engage the Web site's audience. Suggestions as to how this may be done are discussed in section 6.

4. DESIGN AND IMPLEMENTATION

4.1. Design: the subject architecture

The subject architecture is shown in the hierarchy of HTML documents accessible through the standard Web browser user interface. This consists of a multiple-level document tree, up to a maximum of five levels (Ang and Ramani 1998). Content to be presented is organised into an architecture based on the classification hierarchy for Malaysian music. The content included within the individual Web pages is discussed in Ang and Ramani (1998).

Figure 6 concisely illustrates the subject architecture for Malaysian music, constructed based on the classification method (figure 5).

The complete hierarchy of Web pages is contained in Ang (1997b), which shows the site map. Although the document tree structure consists of five levels, all pages within the site may be accessed using a maximum of three mouse clicks from the site home page. This principle is adopted to ensure easy accessibility of all documents within the site, during the course of normal browsing. For fast access, users may locate any page within the site using only two mouse clicks, via the site map page: the first click to view the site map, and the second to view the page desired. Further, to assist users in locating specific information desired, a CGI search script is also implemented. It locates documents containing keywords specified by the user, via an online form.

4.2. Implementation: the application architecture

The application architecture forms the underlying layer of the two-layer Web architecture, and consists essentially of the file storage structure. The application architecture reflects the subject architecture, but does not mirror it exactly. It is organised into several hierarchical directories and subdirectories, the details of which are illustrated in figure 7.

The application architecture exhibits the modular design principle which is adopted in the Web architecture design, with different file types separated into different directories. Figure 7 is essentially a detailed expansion of figure 8. Four main types of files are stored: HTML or text files, multimedia files (comprising digital audio files (`.ra` format), streaming audio and video files (`.viv` format) and MIDI files (`.mid` format)), image files (`.gif` and `.jpg` formats), and utility files, consisting of various scripts.

The HTML files are stored in a directory structure which closely resembles the subject architecture (figure 6). This design provides for ease of extensibility. For example, the addition of the information about a new composer merely involves adding on another subdirectory for that composer under the relevant branch of the directory tree. The Web page template is easily modified from existing composer pages.

The storage of all multimedia files in separate modular directories, by file format, provides for ease of enhancement. For example, a new improved version of the digital audio file format is easily implemented through the replacement of all existing

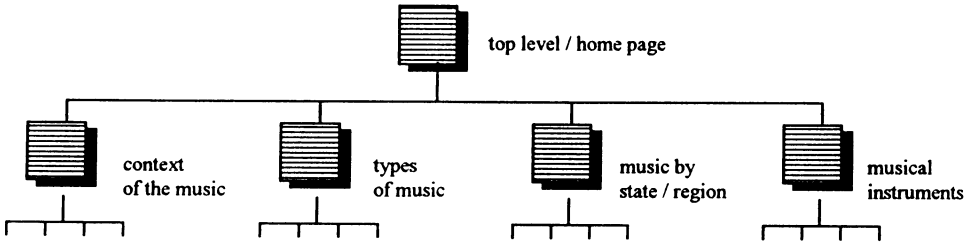

Figure 6. Hierarchical view of web documents by included content.

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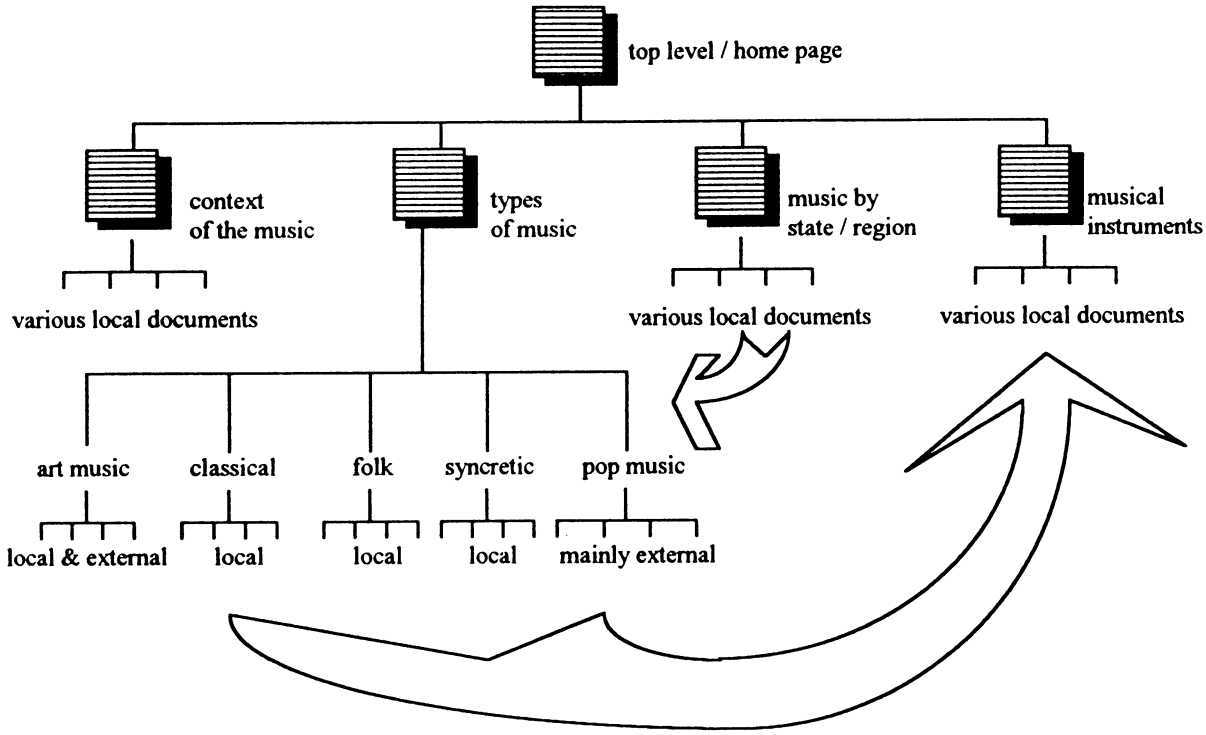

Figure 7. The subject architecture.

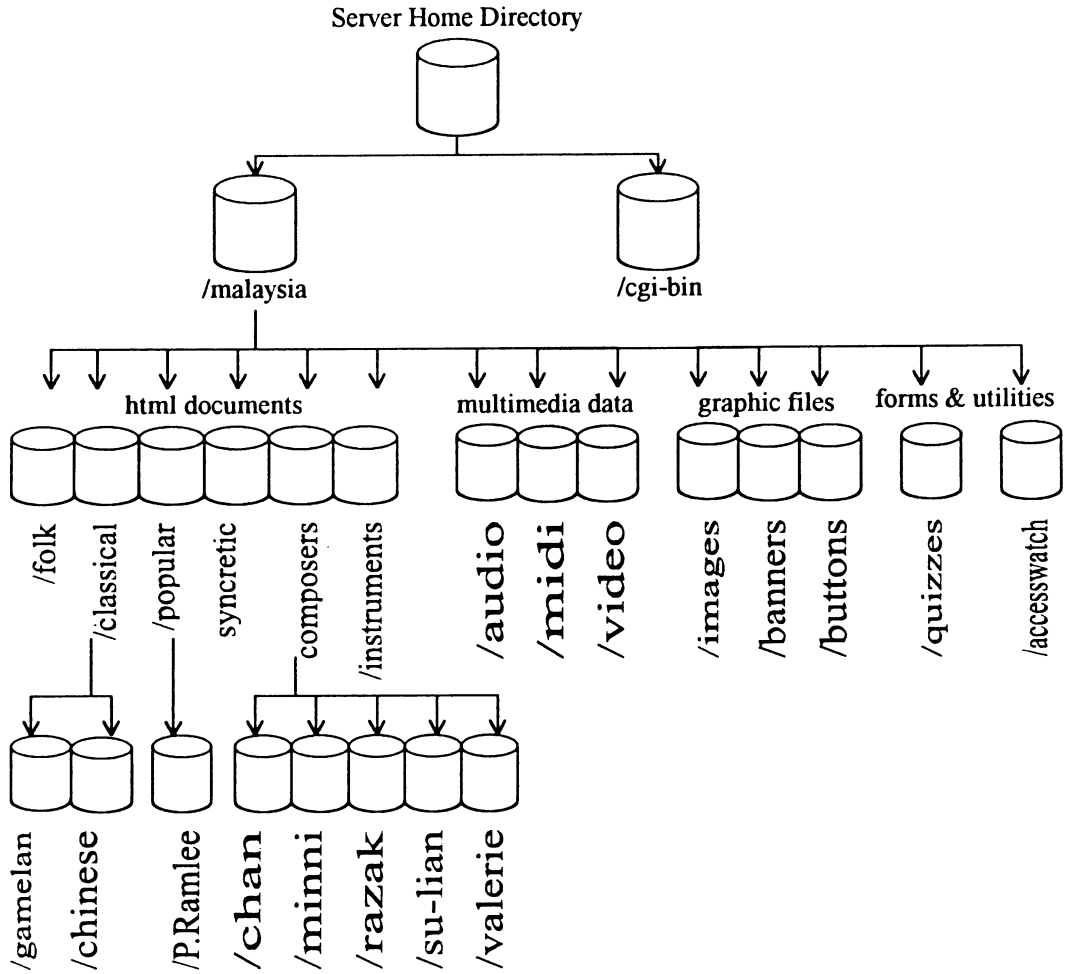

Figure 8. The application architecture in the form of a hierarchical directory tree.

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files in the directory with those encoded in the new format. Links to the specific files from the parent HTML pages need not be updated if the new file format extension and mime-type remain identical; for example, the old `.ra` format may be replaced by a newer version format which still uses the `.ra` extension without having to update anything other than the `.ra` files themselves. Replacement of the existing files with those using a different file extension can be handled through placing the new files into a new subdirectory. The server resource map file can then be updated to include the `Redirect` directive which redirects requests for specified files to the new location.

Image files are stored in three separate directories: `images`, `banners` and `buttons`. The `banners` directory contains all site banner headlines and the `buttons` directory contains icons and similar-function image files, with all other inline images being stored in the `images` directory. Utility files are similarly stored in a separate directory, providing for ease of enhancement and extensibility.

The modular application architecture is easily extensible to include additional directories containing new types of files, for example education modules (consisting of HTML files) which may be built for the purpose of packaging the domain information for the delivery of educational courses.

5. RESULTS AND DISCUSSIONS

The results of the technical analysis, generated using an analytical application, are presented and discussed. The analysis of the prototype Web architecture is carried out in terms of the number of Web pages included within the site, the number and type of links within the HTML pages, the proportion of HTTP links versus links to inline images, the size of Web pages to be downloaded, and the relative download times per page. The results of the server performance testing which was carried out, in terms of time required for the various steps in Web page retrieval, are discussed as an indication of the reliability of the prototype. The prototype Web architecture is also tested in terms of the validity of the links contained in the application.[3] Link validation results are discussed as an indication of the structural robustness of the architecture. The results of the usability analysis, in terms of site promotion, site access statistics and user feedback, are also discussed, as an indication of whether or not the site is successful in achieving its objectives. Site promotion is the process of handling all the public relations issues of a Web site, including making the existence of a Web site known to online communities through publicity. Results of the promotion of the site are discussed. Site access statistics are considered as an indication of whether or not the site is successful in reaching a wide audience, as one of the objectives of the present work is to create a public resource on Malaysian music. Random user feedback is obtained through electronic mail correspondence, guestbook entries and personal interaction with volunteer testers. This is used to qualitatively evaluate the ease of use of the graphical user interface in terms of clarity of instructions (i.e. with regard to on-screen instructions and functionalities), ease of navigation, and simplicity of mixed media file playback. Random user feedback is also used to qualitatively evaluate the clarity of presentation of the content on Malaysian music, i.e. the subject architecture.

5.1. The technical analysis

The Web architecture consists of a total of 170 HTML pages, organised into an underlying structure comprising twenty-three different directories and subdirectories. The average page size is 4,374 bytes. Theoretically, this should take approximately 2.6 s to download over a 14.4 Kbps Internet connection. However, this figure does not take into account the inline images which are usually downloaded together with the HTML page, unless the client browser has the 'auto load images' option turned off. The total size of all pages, including all inline images, is 3,380 KB, averaging 19.9 KB per page. Theoretically, this should take approximately 11.3 s to download over a 14.4 Kbps connection.[4] Browsers generally load the HTML content of the requested Web page first, followed by the inline images. This causes the download process to appear faster to the end user. Download ratings generated by the testing utility rate 73.5% (125 out of 170 pages) of the Web pages included in the application as fast, 21.2% (36 pages) as medium, and 5.3% (9 pages) as slow. 'Fast' pages average 10.7 KB per page, including inline images and take 6.1 s on average to load. 'Medium' pages average 32.4 KB per page and take an average of 18.4 s to load, while 'slow' pages average 96.8 KB in size and take an average of 55.1 s to load. 'Fast' pages consist of an average of 3.3 KB (30.9%) of HTML data and 7.4 KB (69.1%) of inline image data, while 'medium' pages have an average of 4.8 KB (14.8%) of HTML data and 27.6 KB of inline image data

[3] A procedure akin to 'white box testing', which tests that all statements in the program have been executed at least once and all logical conditions exercised (Pressman 1992: 627).

[4] Download time in seconds

$$= \frac{\text{size of page in bits}}{\text{connection speed in bits per second}}$$

$$= \frac{(19.9\ \text{KB}) \times (1024\ \text{B per KB}) \times (8\ \text{b per B})}{(14.4\ \text{Kbps}) \times (1000\ \text{b per Kb})}$$

$$= 11.3\ \text{s}.$$

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Table 3. HTML page size and inline image size data analysis.

% of total number of pages	Average amount of HTML data (KB)	Average theoretical download time for HTML content (s)	Average amount of inline image data (KB)	% of HTML data in total file size	% of image data in total file size	Average total file size (KB)	Average theoretical total page download time (s)	Rating
73.5	3.3	1.9	7.4	30.9	69.1	10.7	6.1	Fast
21.2	4.8	2.7	27.6	14.8	85.2	32.4	18.4	Medium
5.3	7.8	4.4	89.0	8.0	92.0	96.8	55.1	Slow

(85.2%). 'Slow' pages average 7.8 KB (8.0%) of HTML data and 89.0 KB (92.0%) of inline image data. This indicates that the biggest contributing factor in obtaining a 'slow' rating is the added graphic content. The implication here is that any inline images to be included need to be carefully optimised in terms of the file size. A summary of the findings discussed here is given in table 3. Theoretical download times are calculated for the 14.4 Kbps connection.

The acceptable download time targeted for the application, set arbitrarily, is 3 s for a visible response to the user's mouse click, and 15 s for the total page to be loaded. The results in table 3 indicate that the first of these targets is met by 94.7% of the pages included in the application, while the second target is achieved for 73.5% of the pages. This is for connections at 14.4 Kbps. For connections at 28.8 Kbps and more, the first target is met for 100% of the pages, and the second target for 94.7%.

The theoretical download times obtained here are compared with actual download times obtained using an online testing utility. Tests were carried out over a period of three days, with each test consisting of a series of requests sent by the testing utility, at fifteen-minute intervals over a period of eight hours, from the remote site to the server under testing. The average download time for a 10 KB file, as obtained by this utility, is approximately 2.8 s, with no time-outs occurring for any of the pages requested. To compare this result with the results obtained as summarised in table 3, the average theoretical download time for a 10 KB file needs to be extrapolated from the previous results. The download time calculated in this manner results in an average download time of 5.7 s per 10 KB file. This duration is approximately twice as long as the actual download time recorded by the online testing utility, indicating that the connection speed between the two machines is approximately 28 Kbps, i.e. almost twice the connection speed on which the theoretical estimate was based. The 14.4 Kbps connection speed is used as the basis of calculation as this is expected to be the lowest connection speed commonly available to dial-up home users. In practice, many connections may be made at rates higher than this.

The significance of this result is that the actual download times are consistent with theoretical estimates. This implies that both the Web architecture and the server hardware are efficient. Slow download times are generally caused by two classes of shortcomings: server related and application architecture related. Server-related shortcomings arise from insufficient RAM, slow hard disk access rates, CPU overload, and non-caching of frequently requested pages in memory. Architecture-related shortcomings include Web pages generated by CGI scripts or those with Server Side Includes, both of which take additional loading time. The consistency between the theoretical estimate for download time and the actual value obtained through testing indicates that, for the present application, these problems appear not to be an issue.

Download times for digital audio and MIDI files are calculated manually. Streaming audio (`.viv` format) and streaming video files play back while being downloaded, so download times for these types of files do not need to be considered. A summary of the multimedia data available from the prototype application is given in table 4.

The average playback time for digital audio files included in the application is 1 min 57 s. This takes 2 min 6 s to download over a 14.4 Kbps connection, which means that the user has to wait this length of time before hearing any audible output, which lasts for 1 min 57 s on average. The average playback time for MIDI files included in the application is 1 min 36 s, but here the average download time is merely 4.3 s over a 14.4 Kbps connection. The advantage of using MIDI files instead of digital audio is thus immediately apparent. (It is noted here, however, that there are other drawbacks in using MIDI.) Streaming audio is used for longer playback samples, so that the user does not have to wait for the download process to be complete before hearing any audible output, but instead hears the playback as the downloading is carried out.

5.1.1. Link validation results

The number of links available from the total number of pages within the prototype Web architecture is

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Table 4. Multimedia file sizes and download times.

Type of data	File extensions	Total number of files	Average file size (KB)	Average file playback time	Average theoretical total file download time
Digital audio	`.ra`	36	222.3	1 min 57 s	2 min 6 s
MIDI	`.mid`	79	7.8	1 min 36 s	4.3 s
Streaming video	`.viv`	18	277.3	1 min 17 s	Not applicable
Streaming audio	`.viv`	5	477.6	3 min 20 s	Not applicable

3,017, of which 79.1% are http links and 20.1% are image links. The testing indicates that 99.1% of the links are valid while 0.9% are invalid. When tested manually, the 28 links, connecting to 18 unique URLs (all external to the local Web site), listed as 'invalid' were all found to be working. It was found that most of these external sites (comprising 14 unique URLs in total) were simply slow (more than 30 s) to load, causing a time-out error by the testing utility. The remaining four 'invalid' links were caused by the unique functions of the links in question. The two links at the `w23.hitbox.com` site are actually part of the access monitor which returns information to that server via a CGI script, while the two links at `ad-x.com` are remotely generated banner advertisements, included within the prototype as part of the banner exchange program undertaken to promote the Malaysian music Web site.

The link validation results indicate that the Web architecture is structurally sound. The few slow links caused by external URLs, which are outside the control of the local application, are retained within the prototype Web application due to the relevance of the content of these URLs, as supplementary material, to the content on Malaysian music. As evident from the file storage architecture as illustrated in figure 8, and the subject architecture as shown in figure 7, these slow links do not generally disturb the workings of the application, as they are not central to the Web architecture, but peripheral components of the application.

5.1.2. Server performance results

Server performance testing results are summarised in table 5.

The server rating over this period, as awarded by the testing utility, was consistently 'fair'. While this is quite low (i.e. only better than between 20% to 40% of all servers tested by the utility), it should be taken into consideration that the testing utility resides on a server in the USA, while the `music.upm.edu.my` server is in Malaysia, compared with the majority of servers tested, which probably reside in the USA. The actual figures as seen in table 5 indicate that the server, and consequently the Web application, is reliable in terms of clients being able to gain rapid access to the server, without having to face server time-outs.

Table 5. Server performance summary.
(Testing period: 4 a.m. Thurs. 11 to 4 a.m. Sun. 14 December)

Event	Server average for `music.upm.edu.my` (s)	Percentile as compared with other tested servers
Host ping	0.298	34th
DNS look up	0.128	30th
Connect time	0.750	41st
Download time (10 K file)	2.793	35th
Time-outs	0.000	—

5.2. The usability analysis

5.2.1. *Site promotion results*

One of the aims of the prototype application is to provide information on Malaysian music to the general public. As such, users should be able to locate the site using the various search engines on the WWW. ⟨`META NAME`⟩ tags are used in the header section to facilitate location by the various search engines. The Web site is registered with all the major search sites. Testing is carried out by searching the various engines using various related keywords. Examples of search results are shown in table 6. The results indicate that the application is relatively easy to locate on the WWW.

5.2.2. Site statistics for the prototype application

The site access statistics provide an indication of whether or not the online Web resource for Malaysian music is reaching the general public, which was one of the objectives of this work. An analysis of the

Table 6. Example results for search by keywords.
(Search date: 13 December 1997, 5.00 p.m.)

Keywords searched	Engine searched	Highest placement (below 100)
Malaysian music	Alta Vista	5
	CARI	6
	Infoseek	1
	WebCrawler	2
Malaysian composers	Alta Vista	1–4
	CARI	Search term not found
	Infoseek	1
	WebCrawler	1
Malaysian musicians	Alta Vista	6
	CARI	Search term not found
	Infoseek	1
	WebCrawler	Not listed

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Web server access log for the last quarter of 1997 was carried out using a server log analysis application. The Web server receives an average of 828 hits per day, with an average of 206 user sessions, each spending an average of 9 min 13 s at the site. It is interesting to note that 54.21% of these users access the site from the USA, with the remaining 45.79% being spread among the various geographical regions. The Musical Malaysia home page is currently the most requested single page on the server, ranking higher than the more established (i.e. launched about one year earlier) UPM Music Department home page.

The domain from which the site is most frequently accessed is the home user dial-up service provider `tm.net.my`, with Internet service provided by Telekom Malaysia. These accesses accounted for 65.2% of all accesses to the site over a three-month duration (October to December 1997). The implication here is that the majority of those accessing the Web application are home users, i.e. the general public.

The list of most active countries is interesting in that of the top fifteen countries (accounting for 67.38% of total user sessions) accessing the site, 100% of these accesses come from abroad, spanning four different continents. Of these, 80.46% are from the USA, while none are from within Malaysia itself. These results may indicate that users in the USA and other countries abroad generally account for more WWW traffic (i.e. larger number of users) than Malaysian users, or it may indicate that the Web site on Malaysian music is more popular among people abroad than it is among Malaysians within the country. The former reason is found to be true when WWW demographic results are considered (Network Wizards 1997) – of the 19,540,325 hosts on the WWW, only 40,533 are from Malaysia, a meagre 0.21%, so it is hardly surprising that user sessions originating from within the `.my` domain account for so few of the Web site accesses in terms of relative numbers. This does not, however, imply that the site is primarily accessed by non-Malaysians. The only conclusion that may be inferred from these results is that the site is primarily accessed from outside Malaysia. Guestbook entries indicate that the primary users of the Web application at present are actually Malaysians, as implied by user names provided by guests. One inference that may be drawn from this state of events is that the Web application is currently most frequently accessed by Malaysians residing abroad, perhaps primarily by Malaysian students, as it is common knowledge that Malaysian students abroad number in the tens of thousands. This last inference is supported by the activity level results, which indicate peak access during midweek and minimum usage on weekends: university and college students generally access the WWW from their respective schools, which they attend on weekdays.

The activity level by hour of day results show that the site is most frequently accessed at approximately 1 p.m. local time, with a smaller peak occurring at approximately 11 p.m. The period of least activity is at approximately 7 a.m. each day. The interpretation of these results is based on the previous results mentioned in the preceding paragraphs. It is known that the majority of users access the Web site from the USA, while the majority of Malaysian users access the Web site via `tm.net.my` dial-up accounts. Time zones in the USA are between thirteen to sixteen hours behind the Malaysian time zone. The activity level graph indicates that the number of user sessions generally starts to increase from approximately 8 a.m. Malaysian time, or between 4 p.m. to 7 p.m. American time. Peak-level activity occurs at 1 p.m. local time, or between 9 p.m. and midnight in the USA. These results are consistent with the assumption that users are mainly students in the USA who are probably accessing the WWW through on-campus client machines via leased lines, which explains why activity starts to rise after formal class hours. Malaysian users, on the other hand, gain their primary access via dial-up (presumably personal account) connections. Peak usage thus occurs for these users around lunch time (about 1 p.m.) and after dinner time.

These discussions merely reflect the current state of usage of the application. It is noted here that the original primary target audience for the Web application is the Malaysian schools. This audience is, however, new to the WWW and new to the study of music (Ang *et al.* 1998a). Consequently, some promotion or advertisement of the Web application needs to be targeted at this group, before the application gains wide usage. As this is a prototype study, with the main focus being on the design and development of the Web architecture for the delivery of the Malaysian music content over the WWW, the effort to promote the use of the application is not undertaken at this stage. It is, however, mentioned here as a point to note for future action.

Further results obtained from the Web site log analysis show that for the three-month period analysed, 100% of all server hits were successful hits, with no failed hits. This further affirms the server reliability, as indicated in previous paragraphs by the results from the online testing utility.

The results for the most downloaded file types and sizes show that, in terms of numbers of files requested, 68.9% of all requests are for HTML files, 19.6% for MIDI files, 10.2% for digital audio files (`.ra` format), and 1.3% for streaming audio or video files (`.viv` format). The Web architecture contains 170 HTML files (55.2%), 36 digital audio files (11.7%), 79 MIDI files (25.6%), and 23 streaming audio and video files (7.5%). Image files are not mentioned here as they are downloaded as inline images

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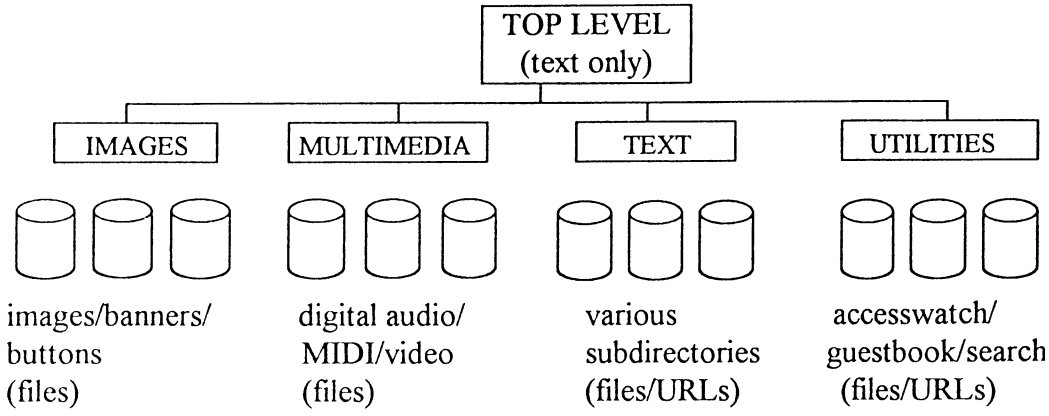

Figure 9. Application architecture essentials.

within the HTML files, and not requested separately by the user. A comparison of the two percentages is presented in figure 9.

Figure 10 shows that the overall profile for different types of files available from the site is similar to the overall profile for the different types of files downloaded by users, with slightly lower download figures being obtained for the multimedia files. While this implies a slight hesitation on the part of the users in downloading additional multimedia information, in general most users do make the conscious choice of downloading the multimedia files linked to a particular Web page. Attention is drawn here to the relatively lower percentage of requests for streaming audio and video (`.viv`) files. This implies that users are not downloading all of the available content (780 downloads of these files were made during the survey period, but this figure is very low when compared with the total of 59,228 downloads made during the same period). This may be due to the fact that the `.viv` format was only recently introduced on the WWW and is consequently not so widely known as yet. The seamless integration of new file types is possible through the automatic installation of browser plug-ins. This process is, however, not 100% automated for the most popular browser on the WWW, Netscape Navigator, which requires the user to make certain choices in installation, perhaps causing many users not to install the required plug-in due to various reasons.

The final set of results obtained is the list of most accessed directories. The Musical Malaysia home directory emerged as the most accessed directory within the server for the period surveyed, accounting for 39% of all accesses, in spite of the fact that the Musical Malaysia Web site was only launched approximately three months previously, as opposed to the top level directory housing the UPM Music Department home pages, which was launched about 18 months previously. This trend indicates that the Musical Malaysia Web site should continue to grow in popularity as it becomes more well known on the WWW, with further enhancements made to the prototype.

5.3. The content analysis

So far, the general response to the Web site is positive and enthusiastic, as indicated by random site guestbook entries. Some positive comments were received from the few noted personalities (in the field of Malaysian music) who visited the site and signed the guestbook. Minor modifications to certain specific content on Malaysian music suggested by these visitors were taken on board and implemented accordingly. The fact that these modifications could be done without difficulty is an indication of the strength of the Web architecture designed. Ease of enhancement through the use of a modular directory tree structure was thus achieved.

User feedback through private electronic mail correspondence to the Web master was also obtained. It is noted here that several users expressed dissatisfaction at the use of MIDI to represent various folk music pieces. Primary reasons cited were lack of authenticity, and poor quality of playback (this is actually

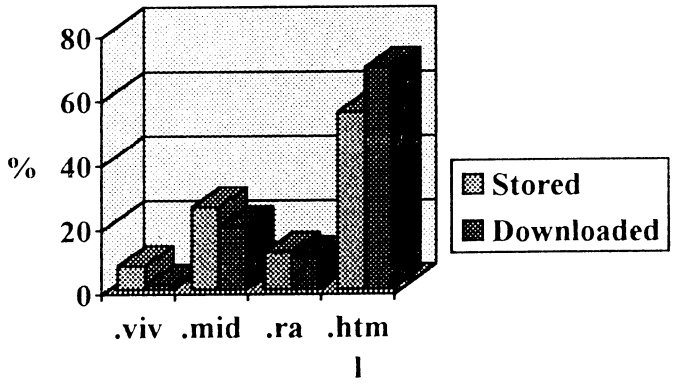

Figure 10. Comparison between relative number of files available from the Web site and relative number of files downloaded by users.

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dependent on the client machine hardware). These users were responded to by return electronic mail, with the justification for the inclusion of MIDI within the site: lack of availability of live recordings, availability of musical scores, and the advantage of being able to print out the representative notation using the appropriate software. (No mention was made of the probably inadequate MIDI playback hardware available to these users, in view of the complexity of the explanation.) It is interesting to note here that research findings by Bridger (1993) indicate that many listeners do actually find computer-generated music disturbing and alienating, a finding confirmed here by these users' responses. Volunteers tested the application for logic of approach (with regards to the content on Malaysian music) and ease of use of the interface. The subject architecture was well received by all volunteers. Minor enhancements to the graphical user interface, i.e. the Web page design, were made on the basis of suggestions by the volunteers; for example, explanatory text was added to certain imagemaps, and the site colour scheme was modified slightly. Again, the well-designed architecture provided for ease of enhancement, and the alterations were made without difficulty.

6. CONCLUSION AND INNOVATION

In conclusion, the two-layered Web architecture (for the delivery of information on Malaysian music), which consists of the visible layer (the subject architecture) and the underlying layer (the application architecture), was found to be a suitable extensible modular architecture which can be applied as a model of Web architecture for music, specifically for the introduction of the music of a particular country or region. The results of the analysis on the prototype Web architecture showed it to be reliable and efficient, having been tested and validated. The Web application also met the general objective of providing a publicly accessible general resource on Malaysian music, as well as specific design objectives, listed below:

- *Portability*. The HTML documents all use relative URLs for internal linking within the local Web site. The application can be easily transferred *en bloc* to another location without upsetting the link information. This was demonstrated when the entire Web site was shifted to another (backup) server without disrupting the links within the site. This portability means that the domain information (the content material on Malaysian music) is not tied to any specific storage device. This allows for easy setup of mirror sites or the transference of the site to a different storage medium (for example CD-ROM), and provides for the continued availability of the information content.
- *Hardware independence*. The Web architecture was implemented on a SunSparc5 server running the Solaris UNIX operating system, but, as explained in the paragraph above, may be easily moved to any platform server.
- *Distributed architecture*. The Web architecture may be conceptualised as consisting of a central core, implemented on the primary local server, but surrounded by essential links to various other URLs containing support information and peripheral components such as the site guestbook. The peripheral components are located at different geographical locations, thus achieving a distributed architecture.
- *Open system*. The client–server architecture required for the complete retrieval and display of the content data is implemented on the WWW, thus achieving an open system.
- *Modular design*. The application architecture is of a modular design. The file storage structure or directory tree was designed so that different types of information and different types of files are stored in different directories.
- *Efficiency of coding*. The high percentage of small HTML file sizes indicates that this design objective was met.
- *Maintainability*. The ease of modifying specific features or contents of the application, such as in response to user feedback, indicates that this design objective was met.
- *Extensibility*. This design objective was also met. This was demonstrated when data gathered in the last stages of the development of the application were easily added on to the existing content.

The results of the prototype performance study are also significant in terms of inferences which can be made: the Web architecture designed is efficient and suitable for the delivery of music-related information content; the application architecture is dependent on the subject architecture; initial accesses, and the listing of the Web site in the various WWW search sites, indicate that the Web application fulfils its purpose in reaching the general public; user feedback received indicates that the Web application fulfils its purpose in providing the public with a broad and understandable introduction to Malaysian music; access statistics indicate that users do generally download multimedia files – although the download time is slower compared with pure text data – if they feel the information provided is worth the effort.

Web-based music education in Malaysia is currently limited to that which is carried out at tertiary level, for example the considerable use of the WWW

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in the teaching of various music courses conducted by the UPM Music Department. The Malaysian schools are, however, still in the early stages of discovering how the computer and the Internet can be applied within the context of classroom education. However, the Malaysian government has stated its commitment to ensuring that, within the next two years, all its schools will be provided with Internet access. In this context, the Web resource on Malaysian music can be of significant use in the teaching of music in Malaysian schools, in line with the objectives of the Malaysian MSC Smart School initiative (MSC 1997).

Suggestions for further development are itemised below:

(1) The extension of the prototype to include educational modules which utilise the information available from the prototype, only packaged differently with the addition of peripheral components such as a larger number of online quizzes.
(2) The adaptation of the architectural model for the development of other Web sites for music education, specifically for the introduction of the music of a particular country or region.
(3) The development of collaborative partner sites for the implementation of the distributed collaborative environment. The lack of currently available potential collaborative partner sites indicates that this is a viable area for future research and development. The extension to the present Web architecture is theoretically not difficult, due to the existing modular, open-system, distributed architectural design adopted.

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