Abstraction Models at System Level for Networked Interactive Multimedia Scripting

by

Jimmy Chi-Ming Lai

Submitted to the Department of Electrical Engineering and Computer Science in Partial Fulfillment of the Requirements for the Degrees of Bachelor of Science in Electrical Engineering and Computer Science and Master of Engineering in Electrical Engineering and Computer Science at the

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Abstract

With the growth of the Web has come a desire for greater interactivity. Unfortunately, the Web currently suffers from some limitations with respect to four parameters for characterizing networked interactive multimedia: Data flow, Spatial and Temporal Synchronization, Media Integration, and User Interactivity.

This thesis extends the ScriptX™ multimedia development platform by building programming abstractions to support desired characteristics of networked, interactive multimedia. The Data Flow Abstraction Model provides network extensions to support data prefetching in the background. The Temporal Synchronization Abstraction Model enhances ScriptX’s support in non-linear synchronization of media playback. The Text-based Media Abstraction Model enables convenient creation of both static and dynamic text media.

With the abstraction models proposed, the extended ScriptX platform has demonstrated to satisfy all of the desired characteristics of networked interactive multimedia.

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Chapter 1

Introduction

The Web is growing at an explosive rate\(^1\); it has evolved into a prototype of the National Information Infrastructure to come [2]. The Web is becoming a pervasive means for people to connect to and publish information on the Internet. The Web offers a likely medium for delivering networked interactive multimedia applications because of its enormous, easily accessible repository of multimedia content. This multimedia content could be made available for retrieval and integration into end-users’ applications. The Web also offers an open architecture that permits developers to continually extend and integrate the work of others. Despite these advantages, the Web is limited in its ability to provide “truly” interactive multimedia.

In general, the composition and presentation of networked interactive multimedia applications (NIMA) involves at least four essential system components. The *Data Flow Component* describes how the data composing the application is delivered on the network to the user, and how the data is managed locally. The *Synchronization Component* deals with both the spatial and temporal organizations of the media elements in the presentation. The *Media Integration Component* describes the types of different media elements in the presentation and the processes through which they are prepared and rendered. The *User Interactivity Component* describes how the users’ inputs are accepted and handled to manipulate the application in an interactive way.

\(^1\) The latest Internet statistics survey [1] has it that the total number of Internet hosts has passed 4.851 million by January 1995 and total users amount to at least 30 million. Worth noting is that “WWW-named host computers now constitute the most numerous on the Internet.” and it brings forth “the largest jump in the recent history of the Internet with a 26% growth rate for 4th Quarter 1994.”
These four system components may be used as assessment criteria to determine the appropriateness of a development / application platform and a delivery medium to author and deliver NIMA. This thesis attempts to address elements of these four components critical to developing and using NIMA.

1.1 Desired Capability for Networked Interactive Multimedia

1.1.1 Data Flow Component: Pre-fetching Model

Due to network bandwidth and local storage limitations, the “download-and-play” model for network distribution of long multimedia presentations is generally not practical. Downloading is expensive, both in time and space. Worse yet, if the user disliked the application, the cost of downloading and waiting has already been incurred.

Pre-fetching offers a possible remedy. Media-rich multimedia presentations generally consists of pre-packaged, individual media objects that are scheduled for rendering at different times. A pre-fetching model permits a multimedia presentation to begin playing with only a part of the entire data, and then pre-fetch subsequent objects during the presentation just before the objects are needed. The model should ensure that the foreground presentation is not affected by the fetching operation. Pre-fetching therefore provides for more efficient usage of network bandwidth and local storage since, at any instance, only a fragment of data is required. The model also provides some flexibility for users to “peek” into the presentation.

1.1.2 Synchronization Component: Spatial and Temporal Orchestration

• Spatial Orchestration

A lively multimedia presentation requires media elements to be positioned appropriately on the screen. Therefore, having the ability to position any object anywhere in the presentation space (a window in most cases) is indispensable. Common scenarios
further require objects to be draggable, scalable, or to be able to bounce around on the screen.

- **Temporal Orchestration**

  In a movie, the three elements of text, video, and sound should be synchronized. For instance, lip motion should match the audio track. There are two notions of temporal synchronization in a media-rich multimedia presentation: *linear synchronization* and *non-linear synchronization*. In linear synchronization, different media objects (e.g. an audio and a video track) are rendered at a constant rate. For example, playing a sound clip 2 seconds after the presentation starts, a video 5 seconds after, and another sound clip 10 seconds after. The main function of linear synchronization is to synchronize the start times for playing back objects throughout a presentation.

  In a non-linear synchronization model, media playback is rendered at rates that change over time. A common example is a moving text stream whose scheduled playback involves flowing out continuously at different rates, pauses, and jumps to render new words at each jump.

1.1.3 Media Component: Common Media and Special Text-based Media

In a media-rich multimedia presentation, media types such as text, graphics, audio, video, and animations are commonly required. However, although rich media enables a lively multimedia presentation, network bandwidth and local storage are always of concern. A 15 minute video clip encoded in MPEG-I [20] at 1.5Mbits/sec takes at least 15 min. to transfer over a T1 line (1.5Mbits/sec), and requires 169M of disk storage. Many existing connections on the Internet are 64kbps leased lines or slower -- at least 23 times slower than a T1 line. A large population of users use dialup services to connect to the Internet through online services like AOL (American Online). Dial-in users are often limited to 28.8 kbps (or slower) modems.
In a networked environment where bandwidth and local storage are concerns, text-based media, though less aesthetic, provides an efficient means for content delivery. Moreover, text-based media could still be attractive. Text can convey a great deal of information. Text can enrich a presentation if it has been richly formatted and is processed by the application. For example, text can be formatted in different colors, sizes or fonts. Text can be dynamically rendered to flow across the screen, or to flash or bounce.

1.1.4 User Interactivity Component: Common Capability and Minimal Latency

User interactivity has to do with providing the means for users to directly manipulate objects within a presentation. Capability requirements vary greatly depending on the type of application. As a minimum, the application platform should provide control mechanisms that are sensitive to user input events, such as mouse moves, mouse position detections, and key presses.

To achieve a “real-time” experience, minimizing the latency in serving a user request is critical. Applications such as interactive adventure games have extreme service latency requirements. Minimizing service latency in processing user inputs generally requires client-side processing. If the interaction is performed by server-side processing, network delay compounds the latency.

1.2 Assessing Interactive Multimedia on the Web

Unfortunately, as a prototype of the NII, the Web cannot meet the criteria specified above for evaluating NIMA.

The Web is based on several interrelated standards, most notably the Hypertext Markup Language (HTML) and the Hypertext Transfer Protocol (HTTP). HTTP is the transport protocol used to communicate between Web servers and Web clients. HTML is a mark-up
“language” that is used to represent the majority of Web documents. Currently, the Web is oriented towards relatively simple static documents. HTML is very limited in its expressive power, even in terms of page layout of static documents. The infrastructure for more dynamic web-based applications apparently does not exist, although the increasing use of forms and server-side CGI (Common Gateway Interface) scripts on the Web reflects the demand for more interactive, networked multimedia applications. Given the list of desired characteristics in section 1.1 for networked interactive multimedia, severe limitations are found with the current Web.

1.2.1 Data Flow Component

The Web only supports pre-loading on a per-document scale and only for text and graphics. Current browsers delay the fetching of inlined graphics within an HTML document, allowing the text portion of the document to be displayed and read by the users first.

Specific Web browsers do support pre-fetching of HTML documents. For instance, Netscape Communications Corporation has implemented a client pull mechanism with its Netscape Web browser that allows a document to be marked with a URL to load after a given number of seconds[4]. Client-pull enables pre-fetching of HTML documents within a presentation. There is no notion of pre-fetching in background mode because an HTML document is presented as static text in the foreground.

True pre-fetching requires that each piece of data in the presentation be able to be prefetched as an independent object and fetched just before use. The Web does not support the prefetching of external media data like video and audio data without user intervention.
1.2.2 Synchronization Component

The needs for both spatial and temporal organization in a multimedia presentation are poorly met by the Web. For spatial organization, HTML is extremely limited in its expressive range, even in terms of page layout for static documents. Features such as tables and multi-column documents, which available, are not yet part of the HTML standard. It is possible to somewhat position objects within the browser window through HTML but the ability commands, to drag, scale, or move objects within a static HTML document is impossible.

For temporal synchronization, common Web browsers only provide minimal, coarse-grained synchronization of media-playback. Media is either rendered in the order that users click on links or waits for control signals from spawned external viewers after the media is cached locally. There is no support for “orchestrated” presentations where the temporal relationships are not only explicitly formulated, but also detailed with great precisions as with synchronizing voice and annotated text.

1.2.3 Media Component

All the common media types can be rendered currently by Web browsers either locally in the HTML documents (text, graphics) or with help from externally spawned helper applications (audio, video, etc.). For formatted text-based media, HTML is the only standard.

1.2.4 User Interactivity Component

The Web currently handles simple user interactions by extending the point-and-click model used to navigate the Web or retrieve data. Fill-in forms are used to accept textual input from users for applications like surveys or online shopping, etc. More advanced interaction is achieved through the use of server-side CGI scripts [5] to generate HTML
documents on the fly (e.g. to report real-time stock exchange information) or to redirect users to another URL.

The Web's model of interactivity is server-oriented, namely, in using the fill-in forms and CGI scripts. This has at least two disadvantages. First, the server can be easily overloaded when there are a large number of clients to be served. Second, server-side processing introduces extra delays in service latency compared to client-side processing because the processed result has to be delivered over the network.

Realizing the usefulness of interactive multimedia on the Web and the limitations presented by lack of client-side processing, many different proposals have been forwarded for client-side extensions. The ideas can be classified into several categories:

1. **Client Push/Server Push**, from The Netscape Communications Corporation [4],

2. **External Programming Support in Browsers** -- such as the NCSA Mosaic CCI (Common Client Interface) [6], Spyglass SDI (Software Development Interface) [7] and Netscape 1.1 OLE2 Automation [8].

3. **Scripting**, namely, CCITcl [17] derived from the combination of SafeTcl [16] and the NCSA Mosaic CCI [6],

4. **Virtual Machine**, namely, the Java project at Sun Microsystems [18]. Virtual machine is a software interpreter for pre-compiled “machine-code”.

Solutions proposed by 1. and 2. above are mainly oriented around extending Web browsers and do not address some of the other limitations discussed in section 1.2 such as synchronization. Among the proposals, scripting and virtual machine seem to be the best approach in providing interactive multimedia on the Web. A major reason is that they provide powerful client-side processing power which the current Web browsers do not have.
This thesis proposes using another platform, ScriptX, which combines the idea of scripting and virtual machine, as a substrate to offer the desired characteristics as discussed in section 1.1. Extensions and enhancements are proposed to make ScriptX satisfy all the characteristics.

1.3 Existing ScriptX Platform

ScriptX (Version 1.0) is a multimedia authoring and distribution product from Kaleida Labs, Inc. ScriptX has been implemented for the Microsoft Windows and Macintosh platforms. It combines scripting with a virtual machine. A virtual machine is a software interpreter of precompiled “machine code”. Application developers use the ScriptX development platform to write scripts to generate multimedia presentations. The scripts are object-oriented. The scripts are then compiled into platform independent bytecode that is distributed and executed by the virtual machine Kaleida Media Player (KMP). ScriptX includes a rich library of multimedia tools such as timers, drawing tools and external media importers for bitmaps, audio (AIFF and WAV), and video (Quicktime and VFW). It provides extensive user interactivity mechanisms such as an underlying search engine for its data objects, and user interface objects like push-buttons and scrollbars. It also has rich system supports such as a tasking mechanism and thread scheduler.

Using ScriptX as a client platform for networked interactive multimedia is close to realizing the desired goals discussed in section 1.1. Specifically, ScriptX provides extensive support for Spatial Synchronization. An object can be placed anywhere within a presentation window, and there is built-in support for making objects draggable and scalable. The User Interactivity support goes beyond the requirements in section 1.1 due to the extensive interactivity support and client-side processing ScriptX provides.
However, as far as the other three system components are concerned, extensions or enhancements are needed for ScriptX to completely satisfy the desired capability.

1.3.1 Insufficiencies of Existing ScriptX Platform

1. Data Flow Component: lack of built-in network support

The current version of ScriptX is a stand-alone package. It does not provide any network interface. Network extensions have to be built into ScriptX to support the prefetching model as described in section 1.1.

2. Temporal Synchronization: lack of structured support for non-linear model

ScriptX has extensive facilities for timing which readily and easily support linear synchronization. Through the use of built-in master-slave relationships, linear synchronizations of media playback is easily attained (details discussed in chapter 5). However, currently there is no structure for supporting non-linear synchronization, although the underlying tools are already in place.

3. Media Component: lack of structured support to prepare individual text-based media

ScriptX provides facilities to display, format (color, sizes, fonts, etc.) and edit text in a multimedia presentation. Text for enriching presentations are usually “hard-wired” into the scripts, with rigid content and format set into the scripts. On many occasions, it would be useful to have individual pre-formatted text files, separated from the scripts, that can be readily imported into ScriptX to produce special text-based media. A common example is a script for a multimedia courseware template. Groups of individual pre-formatted text files which represent slides in a lecture can be imported to the same template to produce the different lecture materials. Moreover, specialized text-based media such as a stream of text which can be rendered dynamically are worth creating since they are useful in most applications.
1.4 Proposed Solutions

To make ScriptX a better platform for developing and delivering network interactive multimedia on the Web which fully satisfies the desired capability as discussed in section 1.1, this thesis proposes building abstraction models to extend or enhance the existing ScriptX platform.

1. Data Flow Abstraction

A network API to be used by ScriptX developers will be designed and implemented. The API will be able to perform background fetching operations. The API will be implemented for the Windows platform.

2. Temporal Synchronization Abstraction

To design and implement a ScriptX class that provides the structure to support non-linear synchronization.

3. Text-based Media Abstraction

To design and implement ScriptX classes that will provide the structure to create formatted, static text media from pre-formatted text files and to create dynamic text stream media.

There are other issues concerning scripting languages in general such as performance due to overhead in interpretation and security. However, those issues are beyond the scope of this thesis.

The remainder of this thesis is divided into six chapters. Chapter two and three describe the design and implementation of the Data Flow Abstraction, respectively. Chapter four describes the design and implementation of the Temporal Synchronization Abstraction. Chapter five discusses the design and implementation of the Text-based
Media Abstraction. Chapter six demonstrates the integrated use of the three abstraction models by building a multimedia presentation. Chapter seven concludes and lays the foundation for future work. The remainder of this thesis assumes a general knowledge about object-oriented programming principles.
Chapter 2

Data Flow Abstraction: The Design

To alleviate the limitation of ScriptX's lack of any built-in network support, the main goal of building the Data Flow Abstraction is to facilitate background fetching of data over the network. Application developers use the ScriptX class BackgroundFetchingAgent as a network API, while details of the design and implementation are "abstracted" away. This chapter discusses the design of the BackgroundFetchingAgent API.

The rest of the chapter is organized into seven sections. Section 1 discusses the current external support that ScriptX can use to deliver applications over the network and the new model for network use offered by this work. Section 2 discusses issues driving the design of the BackgroundFetchingAgent API. Section 3 is a design overview. Section 4 discusses the reasoning behind choosing HTTP as the Network Transport Protocol. Section 5 discusses details of the BackgroundFetchingAgent API. Section 6 gives examples of how to use the API. Finally, section 7 evaluates the API in terms of the original design issues.

2.1 Network Use Models

2.1.1 Current Model without Built-in Network Support

The existing ScriptX platform does not have built-in network support, but it can leverage external facilities such as the Web to provide limited network support. ScriptX titles -- compiled ScriptX scripts in bytecode format that are executed by the Kaleida Media Player (KMP) -- can be delivered as a single data object to be played on client machines running the KMP, by using the Web as the network delivery medium. The following steps
describe the processes involved in delivering ScriptX titles over the network using the Web:

1. Set up the appropriate MIME-type extensions on the local Web browser to launch the KMP as a helper application for executing a ScriptX title.

2. Using a Web browser, find a ScriptX title on some Web server.

3. Retrieve the title using the Web protocol. When the entire title has been downloaded, the browser will launch the KMP to execute the script.

4. Add-ons to a ScriptX title, such as another title with media effects, can be retrieved the same way incorporated into a running KMP ScriptX title.

Such a model requires switching between the Web browser and the KMP, whenever a ScriptX title needs to be retrieved over the network. It also requires that all of the media objects needed by a title be pre-packaged with the title. Every ScriptX title delivered and played this way should be self-sufficient; which means that the whole bulk of the title with all the constituent data in it has to be transferred over the network before rendering.

2.1.2 Proposed Model with Built-in Network Support

This thesis proposes extending the current ScriptX platform by building network support into it. A running ScriptX title will be able to fetch data files in the background over the network and incorporate the data into the title when the whole data file is downloaded. The network use model with the proposed built-in network support will be more flexible than the original model. First, once a title with network support has been delivered to a client (possibly using the Web by means of the steps (1)-(3) in section 2.1.1.), the ScriptX program does not need help from external applications (like a Web browser) to get data over the network. It can any data on the network on its own and incorporate it into the title. Background fetching means that initially only a part of all the data in the presenta-
tion needs to be available to get it started. The rest of the data can be fetched over the net-
work while the presentation is still running. This has certain advantages. First, the
bandwidth and local storage is better utilized, since only a part of the whole presentation
needs to be transferred and stored at a time. Second, new media can be incorporated
dynamically into a title, unlike the original model where media is prepared and packed
into ScriptX titles or libraries.

2.2 Design Issues

There are basically three issues driving the design:

- **Capability**

  The two principle capabilities that this API aims to achieve are described by the two
key words: Fetching and Background. Fetching entails a sequence of client operations:
set up a network connection with a remote server, request a data object from the remote
server, receive the data and store it locally. After the data file has been fetched in whole, it
can be incorporated into the presentation. Fetching should occur in the background. This
implies that a fetch should run silently, not disturbing other system threads and, for multi-
media presentations in particular, not disturb the media rendering and user control in the
foreground. Other desired capabilities include checking the availability of a network con-
nection without actually transferring a file, raising an error on a failed fetch, and stopping
a running fetch operation.

- **Simplicity**

  Creating multimedia applications is a complex and time-consuming task. To make life
easier for application developers, simplicity is very important to save them time when
they use the background fetching facilities in composing an application. In general, appli-
cation developers should worry about nothing more than the remote host/location from which the data is to be fetched, and the local file to which the data is to be saved. This API abstracts implementation details away from multimedia application developers.

• Open Standards

Employing open protocols or open standards in our design is critical. Using the Web as an example, openness ensures that people can extend and integrate other people’s work easily into the Web. The explosive growth of the Web, which is built around open standards (like HTTP), undoubtedly testifies the importance of open standards.

2.3 Design Overview

The design consists of two main elements: the BackgroundFetchingAgent ScriptX class, and the network extension loadable module. The BackgroundFetchingAgent is the API (application programming interface) used by an application developer to access our network extension facilities built for the ScriptX platform. To fetch data over the network, a script will create a new instance of the BackgroundFetchingAgent class in ScriptX, and use its instance methods to do the fetching.

The network extension loadable module provides the underlying mechanisms for network extension facilities to ScriptX. The module identifies a Network Transport Protocol to be employed for the ScriptX clients to communicate with remote servers on the Internet. We have chosen HTTP as our Network Transport Protocol. The rationale for choosing HTTP will be given in a later section. The loadable module is written in C and is dynamically loaded (and linked) into the ScriptX environment when the BackgroundFetchingAgent class is loaded, so that a BackgroundFetchingAgent instance can access the network functions. The ScriptX Loader is responsible for loading in external object files or libraries into the ScriptX environment. A handle to an “entry-point”
function in the loadable module can be obtained from the Loader. This handle allows the
entry-point function to be called within the scripts. The BackgroundFetchingAgent class has a class variable ExtFuncPtr that holds the handle to a function in the network module. As a result, ExtFuncPtr can be used to seamlessly call the functions implemented in the network extension loadable module (see Fig. 2.1).

**Figure 2.1:** Organizational overview of the BackgroundFetchingAgent class

### 2.4 Determining the Network Transport Protocol

HTTP was selected as a natural choice for the network transport protocol because it satisfies the initial design specifications of capability, simplicity and openness. HTTP is a text-
based protocol that runs on top of TCP/IP. After opening a TCP connection to a Web server, a Web client requests an object by sending an HTTP request, using the "GET" method including the path to the desired data. Then the Web server sends back an HTTP reply indicating the status of the request. Upon a successful request and reply handshake, the server sends the object over the TCP connection.

HTTP offers simplicity in that no extra work needs to be done on the server side, except setting up the appropriate MIME types in the HTTP server configuration file. Data objects like ScriptX titles can be readily put on a Web server and retrieved by a client from within the ScriptX environment using the network extension (refer to section 2.1.2).

The greatest advantage of using HTTP lies in the fact that it is the open standard atop which the Web is built. The Web is constitutes an enormous repository of multimedia content. To compose a truly interactive multimedia application, users should have tools to incorporate their own media into the application. Given that the ScriptX network extension we built talks HTTP, it can retrieve data from any Web server and the data can be rendered in a ScriptX program.

2.5 Details of the BackgroundFetchingAgent Class

This section discusses details about the BackgroundFetchingAgent class. The class serves as an API that provides ScriptX developers with network extensions.

Creating and Initializing a New Instance

The following script illustrates how to create a new instance of the BackgroundFetchingAgent class:

```javascript
myAgent := new BackgroundFetchingAgent initMethod: \
  @getSizeNow URL:"http://18.39.0.24/welcome.html" \
  LocalFile:"c/users/jimmy/welcome.htm"
```
initMethod takes a keyword argument @getSizeNow, which tells the new
instance to open a HTTP connection to return the content-length of a specified URL. The
new method of BackgroundFetchingAgent calls its init method and uses the
same keyword arguments. The details of calling the init method are described below:

**SYNOPSIS:**

\[
\text{init } \textit{self} \ [\text{initMethod: name}] \ [\text{URL: string}] \ [\text{LocalFile: string}] 
\]

<table>
<thead>
<tr>
<th>Arguments</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>self</td>
<td>BackgroundFetchingAgent object</td>
</tr>
</tbody>
</table>
| initMethod      | NameClass\(^a\) object. Valid values are @idle, @getSizeNow and @fetchDataNow
|                 | Default value: @idle                                                  |
| URL             | String object. A normal URL pointing to the data needs to be fetched, for instance, “http://18.39.0.24/welcome.html”
|                 | Default value: “” (empty String)                                       |
| LocalFile       | String object. A path in ScriptX style representing the file to store the fetched data. For instance, “c:/users/jimmy/welcome.htm” represents “c:\users\jimmy\welcome.htm” in DOS.
|                 | Default value: “” (empty String)                                       |

**Table 2.1: Arguments of init method**

\(^a\) A NameClass object in ScriptX is a constant value, usually used as a value for a keyword argument to ScriptX functions.

The init method can be applied in one of three ways depending upon the value of the initMethod keyword argument:

1. @idle indicates that the new BackgroundFetchingAgent instance will remain idle
   after creation.

2. @getSizeNow indicates that the new instance will open an HTTP connection
(sending an HTTP request and getting an HTTP reply) to a remote host to determine the size of the data to be fetched. This option is intended for checking network availability, verifying that the remote host can be reached, and that the specified URL is correct.

3. @fetchDataNow indicates that the new instance will open an HTTP connection to the specified remote host and begin retrieving data immediately.

**RETURN VALUE:** After the creation of a new BackgroundFetchingAgent instance, `self`, the instance itself is returned. The `self.Status` instance variable should be checked to determine the status of `self`, especially if `self` has been created with the @getSizeNow or the @fetchDataNow option. `self.Status` reflects the status of network operations. The `Status` instance variable is discussed later in this section.

**Class Variable**

```
ExtFuncPtr
```

`self.ExtFuncPtr` *(read-only)*  Primitive object

`ExtFuncPtr` is a read-only class variable that holds the value of a Primitive object. The Primitive class is used to define the behavior of executable code objects. A Primitive object holds the address of an executable function and the minimum and maximum number of parameters the function requires. `ExtFuncPtr` holds the address of the executable function in the network extension loadable module. Therefore, `ExtFuncPtr` can be used to seamlessly access the network extension facilities. However, under normal circumstances, an application developer will not need to use
ExtFuncPtr. The instance methods of the BackgroundFetchingAgent presents an abstraction that hides the network extensions.

ExtFuncPtr is created as a class variable instead of an instance variable so that the network extension loadable module is loaded the first time the BackgroundFetchingAgent is loaded into the ScriptX environment.

**Instance Variables**

**URL**

*self.URL* (read-write) String object

URL is a read-writable instance variable of type String object. This variable holds the URL that the instance has been initialized with at creation time. For example, "http://18.39.0.24/welcome.html". The value of URL is used to determine the location from which data is retrieved. The value of URL can be reset so that a single BackgroundFetcherAgent instantiation may be used to retrieve multiple data objects. The default value for URL is "" (empty String).

**LocalFile**

*self.LocalFile* (read-write) String object

LocalFile is a read-writable instance variable of type String object. This variable holds the complete path to a file on the client machine for storing data objects retrieved from across the network. The path is given in ScriptX syntax: "c:/users/jimmy/welcome.htm" represents the DOS path "c:\users\jimmy\welcome.htm". The value of LocalFile can be changed and the next fetch using the BackgroundFetcherAgent instance will use the current value of the LocalFile instance variable. The default value for LocalFile is "" (empty String).
Size

self.Size (read-only) Number object

Size is a read-only instance variable of type Number object. This variable holds the size of the data pointed to by the URL instance variable. Size has the appropriate value if the BackgroundFetchingAgent instance has been created using the @getSizeNow option, or the GetSize instance method has been applied explicitly on the instance. The default value for Size is undefined.

Status

self.Status (read-only) NameClass object

Status is a read-only instance variable of type NameClass object. After a new instance of BackgroundFetchingAgent is created, the status instance variable can be queried to reflect the current status of the instance. The value of the Status instance variable is one of four (NameClass) values:

<table>
<thead>
<tr>
<th>Value of self.status (NameClass object)</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>@ready</td>
<td>The instance has been created with either @idle or @getSizeNow option, and the instance is ready for fetching.</td>
</tr>
<tr>
<td>@done</td>
<td>The instance has finished fetching the data.</td>
</tr>
<tr>
<td>@fetching</td>
<td>The instance is now fetching the data.</td>
</tr>
<tr>
<td>@error</td>
<td>An error has occurred. The logString instance variable can be examined for sources of error.</td>
</tr>
</tbody>
</table>

Table 2.2: The Values of the Status Instance Variable
HTTP_REQUEST

`self.HTTP_REQUEST` (read-only) String object

HTTP_REQUEST is a read-only instance variable of type String object. It holds the string representing the HTTP request that is sent to the remote Web server specified by the URL instance variable. HTTP_REQUEST has the appropriate value if the BackgroundFetchingAgent instance has been created using either the @getSizeNow or the @fetchDataNow option, or after either of the GetSize or Fetch instance methods has been applied explicitly on the instance. The default value for HTTP_REQUEST is "" (empty String).

HTTP_REPLY

`self.HTTP_REPLY` (read-only) String object

HTTP_REPLY is a read-only instance variable of type String object. It holds the string representing the HTTP reply received from the remote Web server in response to an HTTP request. HTTP_REPLY has the appropriate value if the BackgroundFetchingAgent instance has been created using either the @getSizeNow or the @fetchDataNow option, or either of the GetSize or Fetch instance methods has been applied explicitly on the instance. The default value for HTTP_REPLY is "" (empty String).

logString

`self.logString` (read-only) String object

logString is a read-only instance variable of type String object. It contains a log of the information about the most recent network session attempted by the BackgroundFetchingAgent instance. If an error occurs during the session, as indicated
by the status instance variable having a @error value, the logString will contain hints for determining the error sources. For example, common errors such as non-existent URL or network failures will be reported in logString.

**Instance Methods**

**GetSize**

*SYNOPSIS:*

GetSize

GetSize self

<table>
<thead>
<tr>
<th>Argument</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>self</td>
<td>BackgroundFetchingAgent object</td>
</tr>
</tbody>
</table>

*Table 2.3: Argument to GetSize Instance Method*

GetSize opens an HTTP connection with the remote Web server specified by self.URL and gets the size of the relevant data object. self.Size will hold the size of data if the operation succeeds.

*RETURN VALUE:* On a successful return, the size of the data pointed to by self.URL will be returned as a Number object and self.Status be set to @ready. If an error occurs, a negative value will be returned, self.Status will be set to @error, and self.logString can be examined to locate error sources.

**Fetch**

*SYNOPSIS:*

Fetch self

<table>
<thead>
<tr>
<th>Argument</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>self</td>
<td>BackgroundFetchingAgent object</td>
</tr>
</tbody>
</table>

*Table 2.4: Argument to Fetch Instance Method*
Fetch opens an HTTP connection with the remote Web server and transfers the data pointed to by self.URL into the file indicated by self.LocalFile. Before fetching, self.status should be set to @ready. During the fetching, self.status is set to @fetching; after completing, self.status is set to @done.

**RETURN VALUE:** On a successful return, the size of the data pointed to by self.URL is returned as a Number object and the data object itself is stored in the file self.LocalFile. self.Status is set to @done. If an error occurs, a negative value is returned, self.Status is set to @error and self.logString can be examined for the source of error.

**Summary of BackgroundFetchingAgent API:**

<table>
<thead>
<tr>
<th>Class Variable</th>
<th>ExtFuncPtr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instance Variables</td>
<td>URL</td>
</tr>
<tr>
<td></td>
<td>LocalFile</td>
</tr>
<tr>
<td></td>
<td>Size</td>
</tr>
<tr>
<td></td>
<td>Status</td>
</tr>
<tr>
<td></td>
<td>HTTP_REQUEST</td>
</tr>
<tr>
<td></td>
<td>HTTP_REPLY</td>
</tr>
<tr>
<td></td>
<td>logString</td>
</tr>
<tr>
<td>Instance Methods</td>
<td>GetSize</td>
</tr>
<tr>
<td></td>
<td>Fetch</td>
</tr>
</tbody>
</table>

Table 2.5: Summary of the BackgroundFetchingAgent API

**2.6 Example Usage of the API**

This section provides several examples that use the BackgroundFetchingAgent API. The examples demonstrate:

1. checking the availability of a network connection without actually transferring a file,

2) two ways to do background fetching,
3) error reporting and error source checking

4) abolishing a running fetch operation.

**Example 1**

```small
class BackgroundFetchingAgent

myAgent := new BackgroundFetchingAgent initMethod: \
    @getSizeNow URL:"http://18.39.0.23/welcome.html"
```

The above script creates a new `BackgroundFetchingAgent` object which, after creation, attempts to make an HTTP request to the remote Web server to determine the content-length of the data indicated by the URL keyword argument. If the script returns successfully, it means that the remote host is accessible and that the URL points to a valid location for the desired data object. A successful return also means that `myAgent.Status` is set to @ready and `myAgent.Size` will have a non-negative value for the size of the data. If an error occurs, `myAgent.Status` will be set to @error and `myAgent.logString` can be used to locate the error source. The same network connection checking can also be done by applying the `GetSize` instance method on an existing `BackgroundFetchingAgent` object as shown in the following script:

```small
myAgent3 := new BackgroundFetchingAgent initMethod:
    @idle URL:"http://18.39.0.23/welcome.html" \
    LocalFile: "c/users/jimmy/welcome.htm"
GetSize myAgent3
```

**Example 2**

In general, there are two ways to perform background fetching using the `BackgroundFetchingAgent` API. One may either fetch at creation time of a `BackgroundFetchingAgent` object or one may apply the `Fetch` instance method on an existing `BackgroundFetchingAgent` object.

```small
(myAgent2 := new BackgroundFetchingAgent initMethod: \
    @isBusy URL:"http://18.39.0.23/welcome.html" \
    LocalFile: "c/users/jimmy/welcome.htm"
```

```small
Fetch myAgent2
```

```small
Abort myAgent2
```
The above script creates a new BackgroundFetchingAgent object which, immediately after creation, attempts to fetch the data pointed to by the URL keyword argument. The use of ‘&’ creates a new thread for the script directing the fetch to run in background mode. During fetching, myAgent.Status is set to @fetching. If the fetch completes successfully, myAgent.Status is set to @done.

    myAgent2.URL := "http://18.39.0.23/picture.gif"
    myAgent2.LocalFile := "c/users/jimmy/pict.gif"
    global t := (Fetch myAgent2 &)

The above script demonstrates the application of the Fetch instance method to an existing BackgroundFetchingAgent object. myAgent2 is reused in this example, and its URL and LocalFile instance variables are set to new values so that a different file is returned. Using ‘&’ in this example creates a new thread for fetching and the thread is assigned to the global variable t (which is the same t in the above script).

    threadKill t

If we want to abolish the running thread t any time during the fetching operation, we can use instance method threadKill of the Thread class in ScriptX to kill the thread.
2.7 Assessing the API in terms of the Design Issues

The BackgroundFetchingAgent API in our design appears to satisfy all three design issues -- capability, simplicity and open standards -- discussed in section 3.1.1.

As the examples provided in section 3.7 demonstrate, the API possesses the four capabilities that we initially sought to achieve:

1. background fetching,
2. checking network availability without transferring a file,
3. error reporting and error source checking,
4. ability to abolish a running fetching operation.

As far as simplicity is concerned, in using the API, application developers need only specify the URL to fetch and a local space to store the returned data. The BackgroundFetchingAgent class looks like an ordinary ScriptX core class to the developers. The underlying network extension implementation is transparent to the developers. In addition, choosing HTTP as our network transport protocol leverages off of the enormous power of the Web -- both as a repository of multimedia data and as a tool for discovery of resources on the Web.
Chapter 3

Data Flow Abstraction: The Implementation

The underlying mechanisms supporting the network extension facilities of the BackgroundFetchingAgent are implemented as a single, loadable object code module written in the C language. This chapter discusses the implementation issues of that object code module.

This chapter is organized into three sections. Section 1 gives an overview of the platform and tools employed, and then discusses environment specific implementation issues. Section 2 discusses the steps taken to ensure that the network extensions run in background mode. Section 3 describes the current status of the implementation.

3.1 The Implementation Environment

The network extension module is implemented on a Pentium 90 PC running Microsoft Windows 3.1. The WinSock API is used as the network programming interface to access Windows network facilities. The Watcom C/C++32 compiler is used to generate 32-bit object modules written in C that are loaded into the ScriptX (Version 1.0) environment by the ScriptX Loader. The Watcom C/C++32 compiler is the only compiler currently being supported by the ScriptX extension interface to write external loadable code on the Windows platform. The following subsections offer a brief overview of the WinSock API, the ScriptX extension interface and issues specific to the implementation due to the characteristics of the extension interface.
3.1.1 The WinSock API

The Windows Socket Application Programming Interface (WinSock API) is used to implement HTTP access in our design by providing functions to manage TCP connections and data transfer. The WinSock API is a library of functions that defines a network programming interface for Microsoft Windows based on the “socket” paradigm popularized by the Berkeley Software Distribution (BSD) of Unix. It encompasses both familiar Berkeley socket style routines and a set of Windows-specific extensions designed to allow the programmer to take advantage of the message-driven nature of Windows.

The WinSock API defines the top level of the WinSock Dynamic-Linked Library (DLL). The WinSock DLL is 16-bit. The WinSock DLL can be dynamically loaded by calling functions in a user application either at load time or at run time. The network module in this implementation loads the DLL at run time, and calls functions in the DLL to access Windows network facilities. The following diagram gives an organizational view of our program accessing the network facilities through the WinSock DLL and any standard TCP/IP stack:

---

3.1.2 ScriptX Extension Interface and Implementation Issues\(^3\)

The ScriptX extension interface allows platform-specific object codes to be loaded in the ScriptX environment to extend the original ScriptX functionalities. On the Windows platform, the Watcom C/C++\(^{32}\) compiler can be used to generate individual 32-bit object files (.obj) or a library file (.lib, a collection of object files) that can be loaded into ScriptX. When the ScriptX Loader loads in a module (single object file or a library file), a single "entry-point" function can be exported to the scripts in ScriptX and called directly by the script passing arguments as ScriptX objects. There are no callbacks from the C world to the ScriptX world except for the SXwriteString function which writes a C string to a

---

ScriptX stream object. There are only three data types that can be freely passed back and forth across the C/ScriptX abstraction barrier: int, double and string. In this development environment, several issues have received special attention in this implementation:

- **Thunking and Indirect Function Calls to 16-bit WinSock DLL Functions**

  Since the Watcom C/C++\(^2\) compiler produces 32-bit object code while the WinSock DLL is 16-bit, the DLL functions cannot be called directly. Instead, the Watcom compiler provides special functions to handle thunking of arguments and calling the 16-bit functions indirectly. When the address of a 16-bit function in a DLL has been obtained (via GetProcAddress() for example), GetIndirectFunctionHandle() can be called to obtain a handle to the function, and thunking the arguments will be done automatically when InvokeIndirectFunction() is then called to execute the 16-bit function. Thunking also needs to be performed when data such as a pointer from the 16-bit world needs to be used in the 32-bit program.

- **Use of SXwriteString for function side-effects**

  Due to the lack of callbacks from loadable code to ScriptX functions (except the SXwriteString function), interaction between the script that calls an external function and the function itself is limited to the single value from the external function that is returned to the caller script. For both the GetSize and Fetch instance methods of the BackgroundFetchingAgent API, three instance variables are updated during a call to the network extension function: HTTP_REQUEST, HTTP_REPLY and logString. The updates are performed by calling the SXwriteString function on the variables which hold the respective String objects (String is a subclass of stream in ScriptX and therefore works with the SXwriteString callback function).
• Single Exported Function for each Loadable Module

The ScriptX Loader only creates a single handle for an exported function in the loadable module. Therefore, if the extension has more than one desired operation, the exported function has to be able to dispatch to execute different subroutines, depending upon a particular argument passed from the scripter level. For the BackgroundFetchingAgent API, two instance methods represent the two desired operations: GetSize and Fetch (refer to section 2.5). Therefore, the above dispatching technique is used.

3.2 Fetching in Background Mode

In the implementation, a combination of the following mechanisms was used to ensure that the fetching process would run in a background mode on Windows. Doing so would minimize the effect on system threads such as ScriptX’s automatic garbage collection or the multimedia presentation being rendered in the foreground.

• Non-blocking Sockets and Asynchronous Functions

Non-blocking sockets and asynchronous functions are provided by the WinSock API to deal with blocking function calls. Many of the socket functions--such as connect(), send(), recv()--take an indeterminate amount of time to execute. When a function exhibits this behavior, it is said to block; calling the function blocks the further execution of the calling program. Because the Windows platform cannot preempt a task (unlike Windows NT and Unix), all other programs are put on hold until the blocking call returns. This would inhibit the ScriptX system threads as well as many others running in the foreground.
To deal with the blocking calls, non-blocking sockets can be created, and WinSock’s asynchronous functions can be used to handle those calls. If a socket is created in blocking mode, the blocking function will not return until the call is completed or a timeout or error occurs. If a socket is created in nonblocking mode, the call to the blocking function returns immediately. A separate function is used to determine the status of the call. The WinSock asynchronous functions were added to WinSock to better fit Berkeley sockets to the message-driven Windows paradigm. Event notification messages are received by an application when a previously called non-blocking function returns. In the meantime, the rest of the program remains fully responsive to the user’s actions.

• Voluntary Yield

Voluntary yields are functions provided by the ScriptX extension API. ScriptX has a system tasking mechanism and a thread scheduler which, together, allocate time slices to run active threads in a pre-ordered, linear sequence. A thread is said to “yield voluntarily” when it relinquishes control even though it has not returned and its time slice has not been expended. If the network extension program runs for a long time, like when fetching a large data object, the tasking mechanism of ScriptX may be disabled for as long as the program runs. Therefore, in the implementation, when receiving the data, once the HTTP handshake with a Web server is done, the program loops, filling a relatively small buffer in each iteration. The program yields to other ScriptX threads upon completion of each iteration.

• Running as a Separate Thread in a ScriptX Title

In addition to yielding voluntarily, the network extension program should run as a separate thread when called from within a ScriptX title. This is probably the most critical step needs to be taken, because if the fetch is run as the same thread as the title thread, it would
freeze some of the title’s rendering. ScriptX provides a shorthand for creating a new thread running a script, by adopting the Unix background thread ‘&’ command notation. For instance “(some scripts &)” will create a separate thread. Creating a separate thread to run the network extension program allows the ScriptX thread scheduler to allocate time slices for network fetching, decreasing the likelihood that a network request will freeze the system.

3.3 Current Status of Implementation

At the time of writing this thesis, all of the functions provided by the Background-FetchingAgent API are supported. Thus the four capabilities noted as design issues in section 2.2 have been satisfied. Currently, the network extension allows fetching a URL in which the remote host is specified by its IP address. A hostname resolution function is not yet implemented. Hostname resolution will be a priority for future work on this project.
Chapter 4

Temporal Synchronization Abstraction

ScriptX’s timing component readily supports linear synchronization. However, there is no built-in structure to handle non-linear synchronization, especially in a networked environment. The purpose of the Temporal Synchronization Abstraction is to support non-linear synchronization. For this purpose, the MasterSlaveContract ScriptX class has been created. This chapter defines linear and non-linear synchronization and then discusses the design and implementation of the MasterSlaveContract class. Examples of how to use the MasterSlaveContract class are given.

4.1 Timing and Linear Synchronization in ScriptX

ScriptX provides fine-grain support for timing and synchronizing time-based operations. Clocks, represented by the Clock class, are used in ScriptX to time and synchronize animation, sound, video, or any other time-based operations. A clock’s time is measured in “ticks”, which is the product of the clock’s rate and its scale. A clock’s rate is measured in sweeps per second; scale indicates the number of tick marks on the face of the clock. To simplify this discussion, subsequent references to clocks and timing in ScriptX assume a scale of 1 unless otherwise specified. Rate (now measured in ticks per second) and local clock time (measured in ticks) are the two quantities of interest.

A clock’s time is controlled by its rate. If the rate is zero, the clock stops. Otherwise, the clock runs at a pace specified by its rate. To synchronize multiple events, clocks can be arranged hierarchically. A Master-and-Slave relationship can be set up between two clocks. Through the master-and-slave relationship, the slave is controlled by manipulating
two parameters: the effective rate (real rate at which the slave runs), and the offset (initial difference in time relative to the master). Both quantities are influenced by the master.

In general, the slave clock's effective rate is a function of its master's effective rate:

\[
\text{Slave's Effective Rate} = \text{Master's Effective Rate} \times \text{Slave's Rate}
\]  \hspace{1cm} [4.1]

If the master clock is a top clock, i.e. not itself a slave of another clock, then it has an effective rate equal to its rate. Thanks to the above equation, the slave can be controlled by solely changing the rate of its master. For instance, consider a slave clock, \(S\), with its rate initially set to 1 (1 tick per second). \(S\) won't run unless its master, \(M\), has a non-zero effective rate. If \(M\) is the top clock, its effective rate equals its rate. If \(M\)'s rate is set at 0, both \(M\) and \(S\) pause. If \(M\)'s rate is set to 1, \(S\) runs at its normal rate of 1 tick per second. If \(M\)'s rate is set to a value larger than 1, \(S\) runs faster than its normal rate. If \(M\)'s rate is set to a negative value, \(S\) runs backwards.

The slave's offset determines the difference in time between the slave clock and the master clock. Since master and slave clocks can run at different rates, the offset specifies this difference at a specific time: when the slave's time is 0. The difference is expressed in ticks of the master. When the slave's offset is any value other than 0, the slave's clock will initially have a negative value when its master clock is at 0. Then, as the master clock runs, and if the slave has non-zero effective rate, the slave's time will reach 0 when the master clock reaches the value of the slave's offset.

In ScriptX, time-based media rendering can be done through the \texttt{Player} class, which is a subclass of \texttt{Clock}. Media players such as the audio player, the video player or animation are all subclasses of \texttt{Player}. Each \texttt{Player} instance or instance of its subclass thus has all the time-based functionalities of \texttt{Clock}. In general, to "play," a \texttt{Player} object sets its rate to 1; to "stop," its rate is set to 0. Media players such as the audio player and
video player start rendering their media when their time reaches 0. To synchronize media rendering in a presentation, a top level master player can be created which has all the media players as its slaves. By specifying the corresponding offsets for each of the slave players and setting each slave’s rate to the normal rate at which it should run, each piece of media is rendered at its respectively scheduled time as the master player runs. The master player acts as the top level control for all media. By changing the rate of the master player, the whole presentation can be paused (master’s rate = 0), fastforwarded (master’s rate > 1), and rewound (master’s rate < 0). Each of the constituent media pieces remain synchronized because each slave’s effective rate is controlled by the master player.

We define the above model of synchronization as linear synchronization. In linear synchronization, the rate of the slave remains unchanged throughout the presentation. By changing the rate of the master alone, the effective rate of each slave changes accordingly. The linear synchronization model is useful for media which is rendered continuously from its start to its end. If we plot out the slave’s time versus the master’s time (see Figure 4.1), it is a straight line with a constant slope equal to the slave’s rate (slave’s effective rate divided by master’s effective rate, according to equation [4.1]). A slave player renders its media when the slave’s time relative to its master reaches 0, when the master player reaches a time equal to the slave’s offset.

![Figure 4.1: Linear Synchronization](image-url)
4.2 Non-linear Synchronization

The linear synchronization model works well if it is not necessary to change the rate at which the constituent media is being rendered. For instance, a video clip being played continuously starting 5 seconds after the presentation begins. However, very often in a multimedia presentation, the constituent media has to be rendered at different rates over time, independent of the other players: pauses, jumps, plays at different rates. A typical plot of the slave’s time versus the master’s time looks like Figure 4.2. The plot is non-linear, not like a straight line as in Figure 4.1.

For a simple and common example: pausing a slave video player (while the master player, and thus other slave media playback, continue) for 3 seconds and then resuming afterwards changes the slave video player’s rate from 1 to 0 (for 3 seconds), then back to 1. In general, changing a slave’s rate explicitly changes the initial linear relationship between the master and the slave. Once this linear relationship is changed, rewinding the master player will not bring the slave back to where it was before the change was made.

![Slave’s Time vs Master’s Time](image)

**Figure 4.2**: Non-linear Synchronization
A new model has to be defined to support non-linear synchronization as in Figure 4.2. For this purpose, the MasterSlaveContract class has been designed and implemented.

### 4.3 Design and Implementation

#### 4.3.1 Design Overview

With a goal of supporting non-linear synchronization, the MasterSlaveContract class is created to provide data structures for representing non-linear timing relations (as in Figure 4.2) between a master and its slaves. At each point in time along the master’s time line, each slave’s time and rate is set accordingly. In general, the slave’s time and rate need to be set explicitly when the master time line reaches a point where the slave’s rate changes (passing time t₂, in Figure 4.2) or when the master’s time jumps (at time t₃, in Figure 4.2). The ScriptX Callback class can be used to call a specified function at certain times or events in a clock’s life cycle. TimeJumpCallback is a subclass of Callback which calls a function whenever a clock’s time jumps. Therefore, TimeJumpCallback objects can be used by the MasterSlaveContract class to update a slave’s time and rate (getting the quantities by querying its timing relation data structure) whenever the master jumps to a new time. TimeCallback is a subclass of Callback. TimeCallback calls a function whenever the specified clock reaches a certain time. TimeCallback objects can be used to update a slave’s time and rate whenever the master reaches a point in the script where a new segment when either one of the two quantities changes.

The MasterMarker class was defined to hold the timing relation between a master and a slave. A MasterMarker object is a “marker” which marks a segment of the master’s time line when the slave has a different rate or when its time jumps.
The MasterSlaveContract class manages a list of MasterMarker objects for each slave. The MasterSlaveContract class creates the corresponding timed callbacks to be called when the master jumps to a new time, or when the master runs into a period marked by another MasterMarker object.

How are the timing relations between a master-slave pair being set up using the MasterSlaveContract class? There are three ways of doing so:

1. **By hardcoding in the script**: In the script, a list of MasterMarker objects can be created explicitly by hardcoding the timing relations between a master and a slave. The MasterMarker objects are added to a MasterSlaveContract object and then the timed-callbacks are initialized.

2. **By incorporating from a timing relation specification string**: An alternative way to establish a master-slave timing relation is by providing a specially formatted string in the script and incorporating that string into the MasterSlaveContract object.

3. **By incorporating from a timing relation specification file**: The third way is to provide a specially formatted file in which the timing specification is given.

The three ways listed above represent a continuum in increasing flexibility for setting up the timing relations of a master-slave pair using the MasterSlaveContract class. The increase in flexibility implies a more suitable means for specifying timing relations in a networked environment for multimedia applications.

The following sections discuss details of the MasterMarker class (examples of each of these three methods are provided in section 4.4) and the MasterSlaveContract class. Examples on how to use the MasterSlaveContract class are also given.
4.3.2 Details of the **MasterMarker** class

The MasterMarker class helps to partition a master player’s time line into separate segments. Each segment specifies a different value of the slave’s rate. A MasterMarker object holds four quantities: master’s segment start time, master’s segment end time, the initial slave’s time, and the slave’s rate during the segment.

**Creating and Initializing a New Instance**

The following script is an example of how to create a new MasterMarker object:

```plaintext
mark := new MasterMarker start:5 finish:10 \ SlaveStartTime: 5 SlaveRate: 0
```

The new method of the MasterMarker class calls its init method and uses the same keyword arguments. The details of calling the init method are described below:

```plaintext
init

SYNOPSIS:

init self [start:num] [finish:num] [SlaveStartTime:num]\ [SlaveRate:num] [string:str]
```

<table>
<thead>
<tr>
<th>Argument</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>self</code></td>
<td>MasterMarker object</td>
</tr>
<tr>
<td><code>start:</code></td>
<td>Number object. Default value: 0</td>
</tr>
<tr>
<td><code>finish:</code></td>
<td>Number object. Default value: 0</td>
</tr>
<tr>
<td><code>SlaveStartTime</code></td>
<td>Number object. Default value: 0</td>
</tr>
<tr>
<td><code>SlaveRate:</code></td>
<td>Number object. Default value: 0</td>
</tr>
</tbody>
</table>

*Table 4.1: Arguments of init Method*
The string: keyword argument is used as an alternative way for creating a new MasterMarker object. Pass as an argument, a string formatted as specified in Table 4.1. This alternative way simplifies the incorporation of timing specifications from a file.

**RETURN VALUE:** A new MasterMarker object is returned.

### Instance Variables

<table>
<thead>
<tr>
<th>Instance Variable</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start</td>
<td>Master's segment start time.</td>
</tr>
<tr>
<td>Finish</td>
<td>Master's segment end time.</td>
</tr>
<tr>
<td>SlaveStartTime</td>
<td>Slave's initial time at the segment start time.</td>
</tr>
<tr>
<td>SlaveRate</td>
<td>Slave’s rate during the segment.</td>
</tr>
</tbody>
</table>

**Table 4.2: Instance Variables for the MasterMarker Class**

4.4 **Details of the MasterSlaveContract class**

The MasterSlaveContract class serves as a contract between the master and the slave. The contract enforces the non-linear synchronization between master and slave. For each slave, a MasterSlaveContract object essentially maintains a list of MasterMarker objects that partition the master's time line into segments. Each segment reflects a change in the slave's rate. The MasterSlaveContract object creates timed callbacks along the master's time line so that when the master jumps to a new time or when the master runs into a new segment, the slave's state (current time and rate) can be updated correctly by looking up the MasterMarker object corresponding to that segment. Default behavior for slaves without any MasterMarker object is linear synchronization.
with the master. Therefore, linear synchronization is a special case of non-linear synchronization.

Creating and Initializing a New Instance

The following script is an example of how to create a new MasterSlaveContract object:

```
contract := new MasterSlaveContract master: m slave: s
```

In the above example, both m and s are instances of the Clock subclass. m is set up as the master; s is the slave. The MasterSlaveContract new method calls its init method, and uses the same keyword arguments. The details of calling the init method are described below:

```
init
```

**SYNOPSIS:**

```
init [self] [master:clock] [slave:clock] [initOffset:num] \[initRate:num]
```

<table>
<thead>
<tr>
<th>Argument</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>self</td>
<td>MasterSlaveContract object</td>
</tr>
<tr>
<td>master:</td>
<td>Clock (or its subclass) object</td>
</tr>
<tr>
<td></td>
<td>Default value: undefined</td>
</tr>
<tr>
<td>slave:</td>
<td>Clock (or its subclass) object</td>
</tr>
<tr>
<td></td>
<td>Default value: undefined</td>
</tr>
<tr>
<td>initOffset:</td>
<td>Number object. Default value: 0</td>
</tr>
<tr>
<td>initRate:</td>
<td>Number object. Default value: 1</td>
</tr>
</tbody>
</table>

**Table 4.3: Arguments to the init Method**

**RETURN VALUE:** A new MasterSlaveContract object is returned. The values of initOffset and initRate specify the initial offset and initial rate for the
slave. If a slave does not have any MasterMarker object attached to it, default behavior is linear synchronization based upon the initial offset (refer to section 4.1). Therefore, linear synchronization is a special case of non-linear synchronization.

**Instance Variables**

<table>
<thead>
<tr>
<th>Instance Variable</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>master</td>
<td>Clock (or its subclass) object, being the master.</td>
</tr>
<tr>
<td>slaves</td>
<td>Array object, holding all the slaves (Clock object, or its subclass)</td>
</tr>
<tr>
<td>SlaveMarkersTable</td>
<td>HashTable object. Each entry has a slave as key and an Array of MasterMarker objects as value.</td>
</tr>
</tbody>
</table>

Table 4.4: Instance Variables of the MasterSlaveContract Class

**Instance Methods**

**AddSlave**

**SYNOPSIS:**

AddSlave self slave

<table>
<thead>
<tr>
<th>Argument</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>self</td>
<td>MasterSlaveContract object</td>
</tr>
<tr>
<td>slave</td>
<td>Clock (or its subclass) object.</td>
</tr>
</tbody>
</table>

Table 4.5: Arguments to AddSlave Instance Method

AddSlave adds a new slave, slave, to the MasterSlaveContract object, self. self.master is set up as slave's master clock. self.slaves is updated.

**RETURN VALUE:** The updated self is returned.
DropSlave

SYNOPSIS:
DropSlave self slave

<table>
<thead>
<tr>
<th>Argument</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>self</td>
<td>MasterSlaveContract object</td>
</tr>
<tr>
<td>slave</td>
<td>Clock (or its subclass) object</td>
</tr>
</tbody>
</table>

Table 4.6: Arguments to DropSlave Instance Method

DropSlave removes slave from self. self.slaves is updated. slave's master clock is set to undefined, and slave's entry in self.SlaveMarkersTable is deleted. Timed callbacks on self.master that correspond to slave are removed.

RETURN VALUE: The updated self is returned.

AddMMarker

SYNOPSIS:
AddMMarker self slave mmarker

<table>
<thead>
<tr>
<th>Argument</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>self</td>
<td>MasterSlaveContract object</td>
</tr>
<tr>
<td>slave</td>
<td>Clock (or its subclass) object</td>
</tr>
<tr>
<td>mmarker</td>
<td>MasterMarker object</td>
</tr>
</tbody>
</table>

Table 4.7: Arguments to AddMMarker Instance Method

AddMMarker adds mmarker, that belongs to slave, to self. self.SlaveMarkersTable will be updated.

RETURN VALUE: The updated self is returned.
**ResetCallbacksForSlave**

**SYNOPSIS:**

ResetCallbacksForSlave *self* slave

<table>
<thead>
<tr>
<th>Argument</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>self</em></td>
<td>MasterSlaveContract object</td>
</tr>
<tr>
<td><em>slave</em></td>
<td>Clock (or its subclass) object.</td>
</tr>
</tbody>
</table>

Table 4.8: Arguments to ResetCallbacksForSlave Instance Method

ResetCallbacksForSlave resets all the timed callbacks that correspond to *slave* on *self*.master. The method is called either when all of the MasterMarker objects for *slave* have been added to *self* using AddMMarker, or when the list of MasterMarker objects for *slave* is modified.

**RETURN VALUE:** *self* is returned.

**ResetCallbacksForAll**

**SYNOPSIS:**

ResetCallbacksForAll *self*

<table>
<thead>
<tr>
<th>Argument</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>self</em></td>
<td>MasterSlaveContract object</td>
</tr>
</tbody>
</table>

Table 4.9: Argument for ResetCallbacksForAll Instance Method

ResetCallbacksForAll resets all the timed callbacks for all of the slaves in *self*.

**RETURN VALUE:** *self* is returned.

**IncSpecForSlave**

**SYNOPSIS:**

IncSpecForSlave *self* slave [dir:d] [path:p] [string:s] \
Table 4.10: Arguments for IncSpecForSlave Instance Method

<table>
<thead>
<tr>
<th>Argument</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>self</td>
<td>MasterSlaveContract object</td>
</tr>
<tr>
<td>slave</td>
<td>Clock (or its subclass) object</td>
</tr>
<tr>
<td>dir:</td>
<td>DirRep(^a) object. Specify the directory to find the specification file. Default value: undefined</td>
</tr>
<tr>
<td>path:</td>
<td>String object. Specify the file name for the specification file. Default value: undefined</td>
</tr>
<tr>
<td>string:</td>
<td>String object. Format: &quot;initOffset,initRate; s1,f1,sst1,sr1;s2,f2,sst2,sr2;...;...&quot; Default value: &quot;&quot; (empty String)</td>
</tr>
<tr>
<td>SectionID:</td>
<td>String object. Default value: &quot;[MSCSPEC]&quot;</td>
</tr>
</tbody>
</table>

\(^a\)A DirRep object represents a directory structure in the corresponding platform in ScriptX.

IncSpecForSlave provides two ways for incorporating timing relations for a slave and setting up the corresponding timed callbacks with the master: by providing either a specification string or a specification file.

1. **Incorporating from a specification string:**

The specification string is of the format:

"initOffset,initRate; s1,f1,sst1,sr1;s2,f2,sst2,sr2;...;..."

where initOffset and initRate are the respective values of the slave’s initial offset and initial rate. If only linear synchronization is required, the string need only specify the initial offset and initial rate values. After the ‘;!’ delimiter, the rest of the substring is a series of four-number units, delimited by ‘;’.

---

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resents the four values, respectively of: segment start time, segment end time, slave's time at segment start, and slave's rate during segment.

2. Incorporating from a specification file:

IncSpecForSlave looks for the specification file specified by dir and path keyword arguments. In the file, the value of SectionID (defaults to "[MSCSPEC]") marks the beginning of the timing relation data in the file to be incorporated. The first empty line or EOF marks the end of the data:

```
[MSCSPEC]  SectionID
20,1;     initoffset,initRate
0,5,0,1; Data Format: s,f,sst,src
5,10,10,0;

[MSCSPEC2]  empty line marks end of data
10;
0,10,0,2;
10,20,20,0;
```

**Figure 4.3: Sample Timing Specification File**

Different values of SectionID correspond to different sections of the file, where the data may be found. Therefore, multiple sets of data can be included in a single file. Figure 4.3 shows a sample timing specification file. initoffset and initRate are the initial offset and initial rate of the slave. Each data line is of the format: "s,f,sst,src;", where s is the segment start time, f is the segment end time, sst is the slave's start time at segment start, src is the slave's rate during the segment.

**RETURN VALUE:** The updated self is returned.
Summary of the MasterSlaveContract class

<table>
<thead>
<tr>
<th>Instance Variables</th>
<th>master</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>slaves</td>
</tr>
<tr>
<td></td>
<td>SlaveMarkersTable</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Instance Methods</th>
<th>AddSlave</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DropSlave</td>
</tr>
<tr>
<td></td>
<td>AddMMarker</td>
</tr>
<tr>
<td></td>
<td>ResetCallbacks-ForSlave</td>
</tr>
<tr>
<td></td>
<td>ResetCallbacks-ForAll</td>
</tr>
<tr>
<td></td>
<td>IncSpecForSlave</td>
</tr>
</tbody>
</table>

Table 4.11: Summary of the MasterSlaveContract Class

4.5 Example usage of the MasterSlaveContract class

This section provides several examples on how to use the MasterSlaveContract class. The examples demonstrate the three different ways of setting up timing specifications for a slave:

1. By hardcoding in the script
2. By incorporating from a string
3. By incorporating from a file

Each of the examples attempt to set up timing specifications for a slave shown in Figure 4.4.

Figure 4.4: Timing Spec. of Slave for all three examples
Example 1

The following script demonstrates setting up the timing relations in Figure 5.4 by hardcoding in the script.

```plaintext
global ml := new player
global sl := new player
global contract1 := new MasterSlaveContract \
    master:ml slave:sl initOffset:5 initRate:2
global mark1 := new MasterMarker start:10 finish:20 \ 
    SlaveStartTime:10 SlaveRate:0
global mark2 := new MasterMarker start:20 finish:30 \ 
    SlaveStartTime:10 SlaveRate:1
global mark3 := new MasterMarker start:30 finish:40 \ 
    SlaveStartTime:50 SlaveRate:0
global mark4 := new MasterMarker start:50 finish:1000 \ 
    SlaveStartTime:50 SlaveRate:1
AddMMarker contract1 sl mark1
AddMMarker contract1 sl mark2
AddMMarker contract1 sl mark3
AddMMarker contract1 sl mark4
ResetCallbacksForSlave contract1 sl
```

Example 2

The following script demonstrates setting up the timing relations in Figure 5.4 by incorporating a string:

```plaintext
global specStr := "5,2;10,20,10,0;20,30,10,1;30,40,50,0;\ 
    50,1000,50,1"
global m2 := new Player
global s2 := new Player
global contract2 := new MasterSlaveContract master: m2\ 
    slave: s2
incSpecForSlave contract2 s2 string:specStr
```
Example 3
The following script demonstrates setting up the timing relations in Figure 5.4 by incorporating a file “ex3.ini”, located at theScriptDir (ScriptX global variable for directory launching the running script), which have the content:

```
[example3]
  5,2;
  10,20,10,0;
  20,30,10,1;
  30,40,50,0;
  50,1000,50,1;

[...]
```

Figure 4.5: Specification File for Example 3

global m3 := new Player
global s3 := new Player
global contract3 := new MasterSlaveContract master:m3 \ slave:s3
incSpecForSlave contract3 s3 dir:theScriptDir \ path:“ex3.ini” SectionID:”[example3]“
Chapter 5

Text-based Media Abstraction

Text is an important medium in most multimedia applications. Richly formatted text moving actively on the screen is commonplace in lively multimedia presentations. For multimedia applications in a networked environment where bandwidth and local storage are concerns, text provides an efficient means of content delivery (because of its small size), and nonetheless an attractive medium if client-side processing of the text is possible. In ScriptX, text has associated attributes that specify its color, font, size, etc. Text formatting is done within a script, and the process requires a great deal of detailed attention that could have been avoided.

The SAText (Static, Annotated Text) class was developed to provide an alternative way to prepare and present formatted text in ScriptX. The SAText class creates formatted Text objects from an annotated source: a string or an ASCII text file. The contents are annotated in the source with formatting command strings. The SAText class is intended to provide a simpler and more flexible way to prepare text-based media in ScriptX. It also allows formatted text to be distributed in a networked environment just like other media such as graphics, audio or video clips, which are separated from the scripts or applications.

The SAText class has been further extended to include the DAText (Dynamic, Annotated Text) class. A DAText object, like a video player, plays a stream of formatted text. Variable rates for playing DAText objects allows fastforward, rewind, and pause, just as in a video player. This chapter discusses the design and implementation of the SAText class and the DAText class. Examples in using the SAText and DAText classes will be given at the end of the chapter.
5.1 Existing Text Support in ScriptX

The Text component in ScriptX provides facilities for the display, editing and formatting of text, including paragraph formatting. The Text component consists of the Text class, TextPresenter class and the TextEdit class. A Text object is a subclass of String. The TextPresenter and TextEdit classes hold Text objects as their “target”, and are responsible for displaying (and editing, for TextEdit) the text. A Text object is more than a string in that the plain text string that it represents, can be formatted by setting its attributes such as size, font, color, to different values. The whole target string is indexed into cursor positions:

```
HELLO
```

<table>
<thead>
<tr>
<th>H</th>
<th>E</th>
<th>L</th>
<th>L</th>
<th>O</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

**Figure 5.1:** Cursor Position and Ordinal Position

To format a part of the string represented by a Text object, application developers specify the range of the cursor positions to format and then apply the instance methods setAttr or setAttrFromTo on the Text object. Formatting text this way with ScriptX is time-consuming, considering the trouble counting the cursor positions to change the attributes.

The current ScriptX features also allow the importing of external text files to create Text objects. Two text file formats are supported: plain ASCII and RTF (rich text format). Imported ascii text files are not translated into plain, ScriptX Text objects with default attributes. Formatting plain text in ScriptX involves applying SetAttr or SetAttrFromTo. An RTF file is a fully formatted document which is used in docu-
mentation like this thesis. RTF needs to be generated from an RTF editor, and is not generally used to prepare lively text-based media for a multimedia presentation.

5.2 The SAText class

5.2.1 Overview

SAText stands for Static, Annotated Text. The SAText class provides a simpler alternative for preparing static, formatted text-based media in ScriptX. The source to an SAText object is either a text string, or an ASCII text file that is annotated with special command strings. Without any annotation in the source, SAText objects are created using the default attributes of Text objects. The SAText class is a subclass of Text. Contents are formatted according to the command string annotations. The command strings are of the form:

@command.argument{foobar}

As the content being annotated, foobar's attributes are set by the command string where the new SAText object is created. A typical source file or source string for creating an SAText object is as follows:

@leading.15{@size.12{Hello, @brush.255:255:0{Colorful @size.24{World!}}}}

Figure 5.2: Sample Source File for Creating SAText Object

Creating the sample source file into a formatted text (SAText object) needs only one line of script:

mytext := new SAText dir:theScriptDir path:"sample.sat"

While using the existing ScriptX support will need the following lines of script:
mytext2 := "Hello, Colorful World!" as Text
setAttr mytext2 @leading 0 15
setAttr mytext2 @size 0 12
setAttr mytext2 @brush 6 (new Brush color: \new RGBcolor red:255 green:255 blue:0)
setAttr mytext2 @size 15 24

As shown in the sample file in Figure 5.2, command strings can be nested within one another. If one content string is annotated by two command strings of the same type, the innermost one takes effect. For instance, in the sample source file, World! is being annotated by both @size.24{} and @size.12{}. @size.24{} dominates because it is the innermost command string to World!. The set of command strings and the possible arguments recognized by the SAText class cover all of the attributes and attribute values supported by ScriptX for formatting a Text object. The set of recognized command strings are listed in the following table:

<table>
<thead>
<tr>
<th>Annotation Keyword</th>
<th>Arguments</th>
</tr>
</thead>
<tbody>
<tr>
<td>@brush</td>
<td>r:g:b (the numbers for red, green, and blue component respectively) e.g. @brush.255:255:255{}</td>
</tr>
<tr>
<td>@font</td>
<td>font (name of a system font) e.g. @font.Times Roman{}</td>
</tr>
<tr>
<td>@size</td>
<td>number (a value in points) e.g. @size.12{}</td>
</tr>
<tr>
<td>@weight</td>
<td>name Possible values:extralight,light,regular,medium,demi-Bold,bold,extraBold,heavy e.g. @weight.bold{}</td>
</tr>
</tbody>
</table>

Table 5.1: Arguments to the Annotation Keywords in SAText Source

5. For more information about what each attribute does to the Text object in ScriptX, refer to p.770 of “The ScriptX Core Classes Reference”[15]
Table 5.1: Arguments to the Annotation Keywords in SAText Source

5.2.2 Details of the SAText Class

The SAText class is a subclass of Text class. It is basically a Text object with its target string’s attributes set according to the formatting annotations of the source, which can be a string or a file.

---

6. For more information about the instance variables and instance methods of SAText class inherited from the Text class, refer to “The ScriptX Core Classes Reference” p.772 [15]
Creating and Initializing a New Instance

The following script illustrates two ways to create a new instance of the SAText class:

1. **Creating from a source file:**
   ```
satext1 := new SAText dir:theScriptDir path:"example.sat"
   ```

2. **Creating from a source string:**
   ```
satext2 := new SAText string:"@size.12{
   @brush.0:255:0{Hello!}}"
   ```

The new method of SAText calls its init method and uses the same keyword arguments. The details of calling the init method are described below:

```init
SYNOPSIS:
init self [dir:d] [path:p] [string: str]
```

<table>
<thead>
<tr>
<th>Argument</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>self</td>
<td>SAText object</td>
</tr>
<tr>
<td>dir:</td>
<td>DirRep object. Specifies the directory of source file. Default value: undefined</td>
</tr>
<tr>
<td>path:</td>
<td>String object. Specifies the file name of source file. Default value: undefined</td>
</tr>
<tr>
<td>string:</td>
<td>String object. Specifies the source string. Default value: &quot;&quot; (empty String).</td>
</tr>
</tbody>
</table>

*Table 5.2: Arguments to init Method*

The init method can be applied in one of two ways:

1. importing from a source file by specifying the location using the dir: and path: arguments

2. importing from a source string using the string: argument.
5.3 The DAText class

5.3.1 Overview

DAText stands for Dynamic, Annotated Text. It is a dynamic version of both the SAText class, and the original Text class. DAText objects are like video players, but they render streams of formatted text strings instead of video frames. In the current implementation, the DAText class is a subclass of both the Player class and the TextPresenter class\(^7\). Subjugation to the Player class permits the DAText objects to exercise play, fastforward, and rewind functionality. DAText objects can also access other time-based facilities through the Clock class (which is the superclass of the Player class). The rate instance variable of a DAText object can be set to render the text at variable rates (positive value for forward rendering, negative value for reverse). Dominance by the TextPresenter class enables the DAText class to render text on the screen. DAText objects can be created the same way SAText objects are created: by using an annotated (or a plain) source string or by importing data from a source file. DAText objects can also be created using existing Text objects to produce moving text.

5.3.2 Details of the DAText class

Creating and initializing a New Instance

The following script illustrates how to create a new instance of the DAText class:

```haskell
datext1 := new DAText dir:theScriptDir path:“example.dat”
```

The new DAText object can then be added to a visible space such as a window and rendered using the play instance method inherited from the Player class. The new method of DAText calls its init method and uses the same keyword arguments.

\(^7\) For more information about the instance variables and instance methods of the Player class and the TextPresenter class, refer to “The ScriptX Core Classes Reference” p.779 and p.575 [15]
init

SYNOPSIS:

init self [dir:d] [path:p] [string: str] [Text:T]

<table>
<thead>
<tr>
<th>Argument</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>self</td>
<td>DAText object</td>
</tr>
<tr>
<td>dir:</td>
<td>DirRep object. Specifies the location for the source file.</td>
</tr>
<tr>
<td></td>
<td>Default value: undefined</td>
</tr>
<tr>
<td>path:</td>
<td>String object. Specifies the file name of source file.</td>
</tr>
<tr>
<td></td>
<td>Default value: undefined</td>
</tr>
<tr>
<td>string:</td>
<td>String object. Specifies the source string.</td>
</tr>
<tr>
<td></td>
<td>Default value: &quot;&quot; (empty String)</td>
</tr>
<tr>
<td>Text:</td>
<td>Text object. Specifies source text.</td>
</tr>
<tr>
<td></td>
<td>Default value: undefined</td>
</tr>
</tbody>
</table>

Table 5.3: Arguments for init Method

A DAText object can be created in one of three ways:

1. **Importing from a source file:**

The Dir: and path: arguments specify the location of the source file to open. The source file contains the annotation command strings defined in the SAText class. If the source file does not have any annotations, then the Text class default attributes are used to create the DAText object.

2. **Importing from a source string:**

The string: argument specifies an annotated (or plain) string as the source for creating a DAText object. If the string is not annotated, the Text class default attributes will be used in creating the DAText object.

3. **Using an existing Text object:**

The Text: argument specifies an existing Text object to be used for creating the DAText object. The attributes of the original Text object are preserved.
Instance Variables

The instance variables that the DAText class inherits from the Player class and the TextPresenter class are discussed here to illustrate the usage of the DAText class.

Instance Variables Inherited from the Clock (through the Player) Class:

rate

self.rate (read-write) Number object

rate is a read-writable instance variable of type Number object. It is used to control the rate at which the DAText object renders its moving text. It measures the number of characters per second that are rendered. A positive rate value indicates forward playback. A negative value indicates reverse playback. Applying the play method on DAText sets its rate to 1. If the DAText object needs to play at some rates other than 1, the rate instance variable has to be set explicitly.

ticks

self.ticks (read-write) Number object

ticks is a read-writable instance variable of type Number object. Since rate measures the number of characters that are rendered per second, the ticks instance variable indicates the number of characters that are already rendered. If ticks is less than 0, then no characters are being rendered. ticks can be set so that for the DAText object will jump to any position in the string.

Instance Variables Inherited from the TextPresenter Class:

target

self.target (read-only) Text object
target is a read-only instance variable of type Text object. target specifies the Text object created by the DAText object. The attributes of self.target are either determined by the annotations in the source (file or string) or by the existing Text object used to create the DAText object.

**Instance Methods**

Some of the instance methods that the DAText class inherits from the Player class, for normal usage are listed in the following table:

<table>
<thead>
<tr>
<th>Instance methods inherited from Player</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>play</td>
<td>sets rate to 1</td>
</tr>
<tr>
<td>fastforward</td>
<td>sets rate to 5</td>
</tr>
<tr>
<td>rewind</td>
<td>sets rate to -5</td>
</tr>
<tr>
<td>stop</td>
<td>sets rate to 0</td>
</tr>
</tbody>
</table>

*Table 5.4: Instance Methods from the Player class*

**5.4 Example usage of the SAText and DAText classes**

This section provides several examples that illustrate the usage of the SAText and DAText classes. The examples demonstrates:

1. Creating a SAText object from a source string and rendering it in a window.

2. Creating a DAText object from a source file and rendering it in a window, with varied rates.

**Example 1**

```plaintext
global win := new window
show win
global sat := new SAText string: \
    "@size.24@brush.255:0:0{Hi!})"
global textpresent := new TextPresenter boundary: \n```

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(new Rect x2:100 y2:50) target:sat
append win textpresent

The above scripts creates and shows a new window, win, and a new SAText object, sat, representing the string “Hi!” in 24 point font in the color red. sat is then put into a TextPresenter object which is rendered in win.

Example 2

global win := new window
show win
global dat := new DAText dir:theScriptDir \ path: "example2.dat"
append win dat
play dat
stop dat
dat.ticks := 20
dat.rate := 5

The above scripts create and display a new window, win. A new DAText object, dat, is created and is rendered in win. The scripts show how to play dat at the default rate (using play), 1, and how to stop (using stop), jump (setting dat.ticks), and play dat at a different rate (setting dat.rate).
Chapter 6.

A Practical Example Using the Abstraction Models

A sample multimedia presentation was developed and implemented in ScriptX to demonstrate the integrated usage of all three abstraction models developed in this thesis. Specifically, the BackgroundFetching, the MasterSlaveContract, and the SAText and DAText classes were used. The sample course uses materials taken from the preview tape of the video course “A New American TQM: Revolutions in Management.” [19]

Scene 1

The following figure shows the appearance of Scene 1:

![Image of Scene 1](image.png)

**Figure 6.1: The Appearance of Scene 1**

Scene 1 is the introduction. A bitmap for the courseware is rendered in the background. A DAText object runs in the foreground at a constant rate throughout
The DAText was created from an annotated source file included as Appendix A. At the bottom of the window are four push-buttons. The buttons exist throughout all scenes in the presentation and are used to control the entire presentation. The functions are: start/restart, play/pause, fastforward and rewind. The buttons were created using ScriptX’s PushButton class. The class activates a function to detect mouse clicks. Each pushbutton function controls the master and, by extensions all of the slave objects. The start/restart button sets the master’s time to 0. The play/pause button sets the master’s rate to 1/0. The fastforward button sets the top player’s time 5 seconds ahead. The rewind button sets the top player’s time 5 seconds backward.

**Scene 2**

![Scene 2](image)

**Figure 6.2: The Appearance of Scene 2**

Scene 2 and scene 3 are lecture materials. In scene 2, three pieces of media are rendered and synchronized spatially and temporally:

1) the lecturer’s picture as a bitmap rendered in the background,
2) a **DAText** object serving as closed-caption text in the foreground, and

3) the lecturer’s voice running continuously as an audio stream.

The closed-caption text is synchronized as a slave to the audio stream so that each word in the text stream is rendered when the audio stream utters that word. The synchronization is done using a **MasterSlaveContract** object created from a timing specification file shown in Appendix A.

During scene 2 playback, a **BackgroundFetchingAgent** object is instantiated to retrieve a file from over the network that will be used in scene 3. The audio playback apparently is not affected by the fetching, since it is automatically set to run at priority by the **ScriptX** system. If the **DAText** object playback in scene 2 is run with a thread with normal priority, it slows noticeably during the background fetch to support scene 3 because the fetch, run as a separate thread, is sharing CPU cycles. However, if the **DAText** object is being run as a thread with high priority, there is no noticeable delay.
Scene 3

The bitmap file fetched during scene 2 is rendered in the background in scene 3. A DAText object runs in the foreground to provide the text for the slide. The lecturer's voice is rendered in an audio stream. The text is synchronized with the audio as in scene 2, using a MasterSlaveContract object. The audio serves as the master; the DAText object as the slave. The MasterSlaveContract object is created from a timing specification file included in Appendix A. Note that scene 2 and scene 3 use the same timing specification file. The SectionID instance variable of the MasterSlaveContract class indicates where in the file the timing data for each scene is located. For example, the MasterSlaveContract object in scene 3 uses "[scene3]" as value to the SectionID instance variable (see Appendix A.4).
Chapter 7

Conclusion and Future Work

7.1 Conclusion

With the abstraction models proposed in this thesis, the extended ScriptX platform has demonstrated to satisfy all of the desired capabilities as discussed in section 1.1 for supporting networked, interactive multimedia. The BackgroundFetchingAgent class in the Data Flow Abstraction provides ScriptX developers with a network API for performing background fetching operations. The example in chapter 6 using the BackgroundFetchingAgent API shows that data can be fetched silently from remote servers without disturbing the presentation running in the foreground provided that running threads that require attention have been set to high priority. The MasterSlaveContract class in the Temporal Synchronization Abstraction has leveraged the existing ScriptX support in timing to support non-linear synchronization enabling the orchestration of media playback where rates change arbitrarily over time. The SAText class in the Text-based Media Abstraction provides a means for creating formatted text media in ScriptX from annotated text files. The DAText class enables the convenient creation of text stream media which can be rendered dynamically. The example application in chapter 6 has demonstrated that all these abstraction models have been successfully implemented.

7.2 Future Work

For the Data Flow Abstraction, hostname resolution is a priority to enhance the existing functionalities of the BackgroundFetchingAgent API. At present, the Data Flow Abstraction is defined to support background prefetching. Several other important
features in the area of data flow are worth added to enlarge the scope of the model. A streaming protocol and buffering to allow live media (e.g. a live video stream) to be played over the network on a ScriptX client are two such enhancements. Live media has advantages for efficient usage of bandwidth and local storage as with the prefetching model. Moreover, compression and decompression can be deployed in future research. Compressed data files can be stored on the servers and decompression by the ScriptX client as part of the retrieval process.

The *Temporal Synchronization Abstraction* currently handles media playback synchronization in a presentation. Protocols to synchronize network fetching with media playback can be developed.

The SAText class presently recognizes command strings that set the attributes of text in ScriptX. More innovative command strings can be implemented to create special media effects to the text content. For instance, `@blink.rate{foobar}` may cause *foobar* to blink with a rate *rate* in the presentation.
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Appendix A

Materials for Preparing the Example in Chapter 7

A.1 The DAText source file in Scene 1

The following source file is used to create the DAText object in scene 1.

```plaintext
@font.Courier New.{@size.20{@Brush.255:255:255{The following Demo shows:

@weight.bold{@Brush.250:250:70{1. Media Abstraction:}}
@leading.20{@indent.25{@Brush.50:255:50{A.}}
@Brush.255:50:50{@style.italic(DAText)} (Dynamic, Annotated Text—the moving
text that you are looking at)
@Brush.50:255:50{B.} @Brush.255:50:50{@style.italic(SAText)} (Static,
Annotated Text -- the static version of
@Brush.255:50:50{@style.italic(DAText))})}}

@weight.bold{@Brush.250:250:70{2. Time Abstraction:}}
@leading.20{@indent.25{@Brush.50:255:50{A.} Linear Synchronization (using
@Brush.255:50:50({@style.italic{Master-Slave Offset}}))
@Brush.50:255:50{B.) Nonlinear Syn. (using
@Brush.255:50:50{@style.italic{Master-Slave Contract}}))}}

===> Be able to FF/Rewind/Jump to any position in the content.}}
```

A.2 The DAText source file in Scene 2 for the Closed-caption Text

```plaintext
@paraleading.10{@Brush.255:255:255{@font.Courier
New{@alignment.flush{@leading.40{@size.20{@weight.bold{Today, I want to
speak of the @Brush.50:255:50{@style.italic{Proactive
Improvement}}. But before going to the
@Brush.50:255:50{@style.italic(Proactive Improvement)), let's review
four revolutions in the Management Thinking. ))))))
```

A.3 The DAText source file in Scene 3 for the Slide’s Text

```plaintext
@post.{@alignment.center{The Four Revolutions in
@Brush.5:0:150{@font.Times New
Roman{@weight.bold{Management Thinking}}))))))))@pause.5()

@play.10{}@size.30{@alignment.flushleft{@brush.84:240:90{@size.30{1.}}
@font.Times New Roman{@brush.250:250:70{@post.(Customer)
@post.{Focus))}}))))@pause.5()

@size.30{@alignment.flushleft{@brush.84:240:90{@size.30{2.}} @font.Times
New Roman{@brush.250:250:70{Continuous Improvement}}))}))))@pause.5()

@play.10{}@size.30{@alignment.flushleft{@brush.84:240:90{@size.30{3.}}
@font.Times New Roman{@brush.250:250:70{Total Participation}}))))))))@pause.5()

@size.30{@alignment.flushleft{@brush.84:240:90{@size.30{4.}} @font.Times
New Roman{@brush.250:250:70{Societal Networking}}))}))))@pause.5()

@size.16{@font.Times New Roman{@weight.bold{
@alignment.flushright{@brush.250:250:250{(The END of Demo))}}}
```

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A.4 Timing Specification file for slaves in scene 2 and scene 3

The following file shows the timing specification file used by the MasterSlaveContract class in both scene 2 and scene 3 to synchronize the DAText objects (as the slaves) to the audio (as the master). "[scene2ccap]" is for scene 2; "[scene3]" for scene 3.

```
-- Filename: expspec.ini
-- the specification file for MasterSlaveContract in scene 2 and 3
-- format: [MSCSPEC]
initialOffset;
start,finish,ticks,rate;
......

[scene2ccap]
0,0;
0,5,0,0;
5,50,9,0;
50,100,18,0;
100,200,32,0;
200,300,41,0;
300,457,55,0;
457,565,68,0;
565,643,80,0;
643,701,92,0;
701,807,105,0;
807,1000,118,0;
1000,1168,124,0;
1168,1276,135,0;
1276,1327,142,0;
1327,1380,153,0;
1380,1500,163,0;

[scene3]
0,0;
0,390,2,0;
352,402,6,0;
402,452,10,0;
452,538,22,0;
538,648,48,0;
800,900,63,0;
900,1200,68,0;
1200,1350,87,0;
1350,1580,100,0;
1620,1750,112,0;
1750,2050,126,0;
2100,2200,141,0;
2200,2300,155,0;
2500,2500,156,3;
```