

# The Structure of the Pyramidia E-learning Tool – the Programmer’s Point of View

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**Abstract** – Pyramidia is a straightforward and easy-to-use software tool developed to record lectures. It records the video and audio of the lecturer and his activities, everything that happens on the screen of the lecturer’s computer and all audio output from the computer. In addition to standard notes, the tool allows the author to add structured content to the PowerPoint presentation: examples, external links and quizzes. Pyramidia enables the lecturer to rapidly record the lecture, package PowerPoint presentations and the additional information they contain and distribute the recording to students with ease. This paper describes the developing process of Pyramidia, its subsystems and their interrelation.

## 1. INTRODUCTION TO PYRAMIDIA

Even though there are many ways to transfer knowledge these days, lecturing is and will continue to be the most dominant method [1], even in the academic community [2,3]. However, it is far from being perfect. Lecturing suffers from its time constraints and students simply can’t properly process all the information presented to them [4].

Video and audio recording of a lecture allows students to view them as many times they seem necessary to fully comprehend the subject. The easiest way to preserve a lecture in its original form is to record it. It is not only the lecturer and his activity (using the blackboard, performing an experiment, etc.) that have to be recorded, but also the display of the lecturer’s computer. Therefore, a recorded lecture should consist of three media streams: a video and audio recording of the lecturer and a video recording of the content the lecturer is presenting to the students, e.g. the computer display presented via a LCD projector. It is important for such a tool to require as little effort as possible from the lecturer, thus simplicity must be a key factor during the development of such a tool.

The assumption of broad usage of MS PowerPoint among lecturers was accepted [5] and the PowerPoint presentation has been used as the central content to which all additional information will be added.

As a result, the project plan behind Pyramidia was to develop an easy-to-use software to preserve and enrich lectures with additional content provided by the lecturer. It combines two important elements of learning into a single e-learning system. The first one is the introduction of additional content and interactivity to existing PowerPoint presentations, and the second one is the live video recording of a lecture, which helps students preserve the lecture in its original form. A more thorough description of Pyramidia and its functionality is given in [6].

## 2. THE PYRAMIDIA LECTURING PROCESS

This is a rather simple and automated lecture capturing (recording) and presentation process. The input to this process is a live multimedia lecture. An ideal lecture should consist not only of the lecturer and a blackboard but of a digital presentation as well. This process is laid out in figure 1.

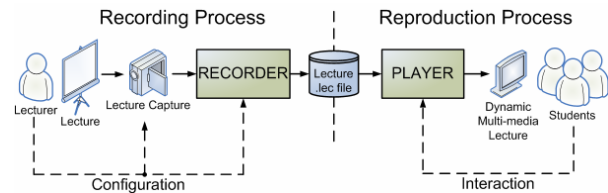


Fig. 1. The Pyramidia lecturing process flow-chart

The process structure resembles a one way pipeline-like structure. In addition to presenting the lecture, the lecturer can adjust the configuration of the Lecture Capture and Recorder elements. Similarly, in addition to viewing the recorded lectures, students can interact with the context sensitive additional content presented by the Player element.

There is no direct connection or content flow between the Recorder and the Player as illustrated in figure 1. They are connected by a .lec file which is the output of the Recorder, and is distributed to the students as the input for the Player, as illustrated in figure 1. This file is somewhat of an intermediate result in the whole process and acts as a data register between the recording and reproduction processes. The .lec file isn’t the only output from the Recorder nor does it contain the whole recorded lecture. It does, however, describe how to combine all of the other Recorder outputs into one dynamic multimedia lecture. The recorded media and additional materials are stored in separate files.

### Technologies Used

Pyramidia uses Microsoft Windows as the development platform due to the popularity of PowerPoint.

DirectShow was chosen as the multimedia framework and API (Application Programming Interface) over possible alternatives, such as Virtual Dub, for a variety of reasons. One reason is the support of ASF (Advanced Systems File) files. ASF files, like most media container files, support multiple compressed media streams. The

difference is in the codecs it supports, such as the MSScreen Encoder codec, which is a video codec developed specifically for compressing computer screen recordings. Due to the nature of desktop geometry, using other video codecs for compression would result in a large loss in quality when used for recording the desktop, which is a major feature of Pyramidia. In addition, its good design and flexibility are other reasons for choosing DirectShow

The .NET framework was chosen to create Pyramidia because it greatly simplifies creating Windows based applications. Another reason for choosing it over other similar frameworks, such as Java, is its support for COM (Component Object Module) which is the technology behind DirectShow. High end applications of Pyramidia are written in C# while the low-level manager subsystems are written in managed C++.

### 3. THE REPRODUCTION PROCESS – THE PLAYER

The Player application allows students to review recorded lectures as many times as they want. This application differs from other multimedia playback applications because it has interactive, context sensitive, enriched content and an advanced navigation system. Students can navigate the recording by jumping to the beginning of any presentation slide, searching the recording for a key word or jumping to a bookmark they placed in an earlier viewing of the lecture. Students can interact with the lecture by open context sensitive links to additional materials that can be local (distributed with the lectures) or accessed over the internet. Another way students can interact with lectures is answering questions to assess their knowledge. Lecture playback is automatically paused anytime students may be distracted from viewing the lecture, e.g. by opening additional materials or answering questions.

The Player consists of two important subsystems, a DirectShow Manager and a Timer. Its structure is shown in figure 2.

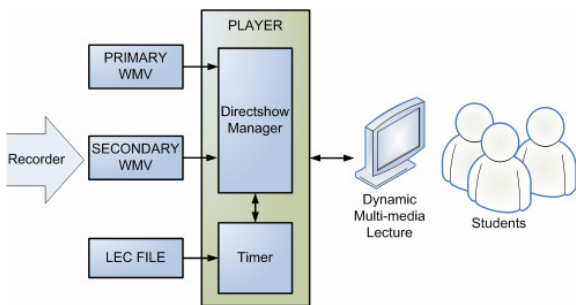


Fig. 2. The Pyramidia reproduction process

The Player accepts three inputs: the primary and secondary WMV (Windows Media Video) files and the LEC file. The primary WMV file contains the primary video and audio stream. The secondary WMV file contains the secondary video stream. The LEC file contains all the information needed to describe a dynamic multimedia lecture. Its structure will be explained in more detail in the Recorder section.

### Player DirectShow Manager

The Player's DirectShow manager acts as a high level interface to DirectShow. This subsystem hides all the low-level details of DirectShow from the Player application and accepts simple commands such as play, pause, etc. This main task of this subsystem is the construction of and interaction with DirectShow filter graphs. A DirectShow filter graph is, as its name suggests, a graph of filters. Filters operate on media samples (video and audio samples). There are many types of filters: source filters, transformation filters, render filters, etc., and each can have any number of inputs and outputs. These filters are connected into a directed graph-like structure to form a multimedia processing system. The Player filter graph consists of file reader filters, media splitters, decompressors and ultimately, rendering filters. For audio, the default DirectShow sound output is used. The video renderers are more advanced custom components that extends the .NET System.Windows.Forms.Form class and use the DirectShow VMR9 (Video Mixer Renderer) object for video rendering.

### Timer

The Timer subsystem is essential for creating the dynamic lecture content. This subsystem is responsible for keeping track of time and updating the dynamic lecture content as necessary. In order to achieve this, the Player creates a lecture timeline based on the lecture event information stored in the LEC file. The timeline consists of timeframes. A timeframe is defined by its start time and its end time, as well as the content that is to be presented during its time interval. The timer subsystem checks every half a second to determine the current lecture timeframe. If the content in that timeframe is different than the content currently on screen, it is updated.

## 4. THE RECORDING PROCESS

### 4.1 The Enriching Process

Dynamic, enriched lectures are a key feature of Pyramidia. In order to create such lectures, certain preparations should be made prior to the recording process. These preparations consist of enriching the PowerPoint presentations used in lectures with additional content. This process is made easy by using the Pyramidia PowerPoint plug-in. The additional content can be added either to already existing presentations or during the creation of a new presentation. The enriching process is shown in figure 3.

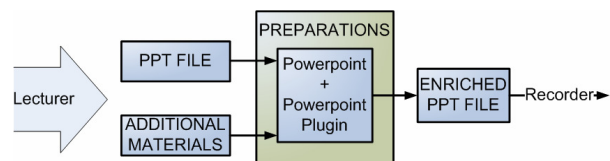


Fig. 3. The process of enriching existing .ppt files

An important feature of the Pyramidia Recorder is the possibility of adding new and modifying existing additional

content after the lecture had been captured and the .lec file had already been created. This is convenient because the lecture does not have to be re-recorded, only the .lec file is updated.

#### PowerPoint Plug-in

The PowerPoint plug-in is a standard MS Office extension written in C# and is used to enrich PowerPoint presentations with additional content. The plug-in is a toolbar which is available in PowerPoint after the installation of the Pyramidia Recorder application. The toolbar consists of three buttons, one for each type of additional content (links, questions and indices).

The additional content is entered through a simple and intuitive GUI (Graphical User Interface), and it is always attached to the current slide. The GUI itself is a C# form. All the additional content is stored in the presentation (.ppt) file which makes handling the content (file) very easy. It also makes it very easy for the author/lecturer to later view and edit the entire content using the same GUI.

Hidden from the sight of the lecturer, each slide's additional content is stored as text in an invisible textbox. The format in which the additional content is stored is a XML format called ECF - Extended Content Format. The invisible textbox is distinguished among others by its unique name, a ECID (Extended Content ID), which is a subtype of GUID (Globally Unique Identifier).

#### 4.2 Capturing the Lecture

The lecture recording process provides students with audio and visual lecture content. This process is carried out by hardware capture devices such as DV cameras, LAN cameras, sound cards, microphones, etc. Because such a vast variety of capture devices exist, it is desirable to use a common interface for these devices. Conveniently, DirectShow supplies such a common interface.

Even though one video and one audio stream would provide some insight into the lecture, it is recommended to use two video feeds to provide a greater lecture viewing experience. These two video feeds are referred to as the primary and secondary videos.

The primary video is intended to contain the more important primary visual content of a lecture. Even though any video capture device that implements a DirectShow video capture filter can be used as its source, it is highly recommended to use the Pyramidia Screen Capture video source as the primary video source. In this case, the visual content of the lecturer's computer display (which is typically shown to students using a projector) is recorded. This is very useful because all the programs used on the lecturer's computer during the lecture are recorded, unlike with other commercial presentation tools, e.g. MS Producer, that would only record the PowerPoint presentation slides. If the lecturer uses a smart board or some other "inking" device, everything handwritten on the desktop/screen will be recorded as well.

The secondary video is intended to focus on the lecturer and possibly the blackboard. Like the primary video, this video's source can be any video capture device that implements a DirectShow video capture filter. This video source will usually be a DV camera recording the lecturer's area of movement. Even though the primary video is

intended to contain more important information, there are times when the secondary stream may be of more interest to students, e.g. the lecturer is performing an experiment or solving a mathematical problem on the blackboard. In these cases, the students are provided with a swap option in the Player application to swap the primary and secondary video during lecture playback.

The audio stream is acquired by the sound card installed in the host computer. Most modern PCs have sound cards build into their motherboards so this hardware is generally provided by default. Most of these sound cards provide basic audio mixing capabilities. This feature allows multiple audio channels to be mixed together forming the lecture audio stream. For example, a microphone channel may be mixed with the computer stereo output channel to include both the lecturer's voice and the sound produced by the computer in the lecture audio stream.

#### Pyramidia Screen Capture

The Pyramidia Screen Capture video source is a DirectShow source filter written in plain C++. This filter emulates a video source and delivers the computer screen content as its video samples. The filter has several properties that can be set. These properties define the frame rate and sample format. A maximum frame rate of 30 fps is defined. However, this value typically should not be larger than 5 to avoid straining the CPU during the encoding process. This filter uses the filter graph's clock to maintain a constant frame rate. The current supported sample formats are RGB32, RGB24, RGB565 and RGB555.

#### 4.3 Recorder

The Recorder is an application that integrates all the lecture elements into a single output, the Pyramidia lecture format. This application accepts many inputs: the audio and video feeds of a lecture, a PowerPoint presentation enriched with additional content and PowerPoint events. An overview of the recorder element is shown in figure 4.

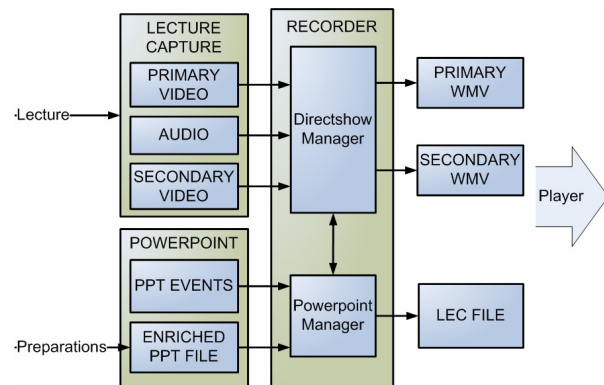


Fig. 4. The structure of the Recorder

The recorder application, similar to the Player, consists of two main subsystems, the DirectShow Manager and the PowerPoint Manager.

## DirectShow Manager

The Recorder DirectShow Manager has the same purpose as the Player one, to act as a high-level interface to DirectShow. The Recorder's DirectShow Manager basically extends the Player's DirectShow Manager by introducing a new command, record. When recording, the constructed filter graph mainly consists of two ASF Writer filters. These filters accept up to one video and one audio input, compress their samples and write them to a file, specifically an ASF file. The compression parameters can be easily set by a GUI provided by the Recorder application. These parameters should be set before the recording process and determine the performance of compression and the size of the output.

The first ASF Writer filter is connected to the primary video and audio streams while the second one is connected to the secondary video stream. All the media streams are synchronized because the two ASF Writer filters share a common clock.

## PowerPoint Manager

This subsystem performs two main tasks. The first task is monitoring all the open PowerPoint presentations and maintaining an up-to-date collection of the currently available additional content. This implies that lecturers can seamlessly use many presentations in their lectures without worrying that their additional content will be mixed up. The second task is catching key PowerPoint events: slide transitions, the beginning and the end of slide shows and opening new presentations. These tasks are made possible by the Microsoft Office Interop Objects. These objects are an API (Application Programming Interface) for controlling many aspects of Microsoft Office applications and basically allow the PowerPoint Manager to closely interact with PowerPoint.

To accomplish its first task, the PowerPoint Manager iterates through all open PowerPoint presentations upon initialization and parses them for any Pyramidia specific additional content. To keep the collection of the additional content up-to-date, the PowerPoint Manager tracks newly opened presentations and parses them too. Newly opened presentations can be detected by handling the appropriate PowerPoint event.

The second task is accomplished by catching other various PowerPoint events. Every time an event occurs, the PowerPoint manager obtains the current stream time from the DirectShow Manager and binds that time to the event caught. These events are ultimately stored in the lecture file and are used to create the lecture timeline. The specific events caught by this subsystem are:

1. PresentationOpen – This event is used to keep the open addition content collection up-to-date. When the subsystem accepts this event, the newly open presentation is parsed for additional content.
2. SlideShowNextSlide – Informs the subsystem that a slide transition has occurred. This information is crucial for creating a dynamic, context sensitive content for students.
3. SlideShowEnd – Informs the subsystem that the presentation has ended.

## Recorder Outputs

The main output of the recording process is the lecture file. This file contains all the information that describes a lecture. It is formatted as a XML file and has the “.lec” extension. The information stored in this file consists of basic information about the lecture such as the lecture name, date, location, etc. The paths to the recorded media files and any additional materials are also stored in this file. Finally, all of the recorded events and additional content are stored in this file.

In addition to the .lec file, a directory with the same name as the lecture file is also created. This directory contains the recorded media files, and all the additional materials (.pdf files, .doc files, etc.) associated to the lecture. These materials are the targets of links defined by the additional content added to .ppt files by the PowerPoint Plug-in.

## 5. CONCLUSION

The current implementation and use of this simple-to-use, yet complex tool, justified the need for it. The Microsoft technologies chosen for creating this tool proved fit for the task. Some issues regarding computer performance were identified. Live encoding of two video and one audio stream have been found very demanding on average PCs used today. While increased processing power of future PCs will overcome this problem, some alternate approaches are being researched, such as buffering uncompressed streams on disk during the recording process and compressing them at a later time in an off-live process.

While concept and design of Pyramidia is based on almost eight years of experience in lecture recording, true usability of Pyramidia will be achieved only as more practitioners implement and use it in their daily routine.

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