The Performance of Ubiquitous Video Conferencing Application

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Abstract - Based on the concepts and the collaborative movement of the Semantic Web, the CSULA SPACE Center¹ has proposed and developed the Semantic Information System (SIS) Network for the real-time project collaboration [1] [2]. The SIS allows users to create, modify, and organize project data in a hierarchical manner. In order to effectively communicate with each other, SIS project collaborators require a uniform, real-time communication platform. In order to avoid the dependency on the third-party applications, as well as to provide a uniform and integrated environment, the Ubiquitous Video Conferencing (UVC) application has been developed. It fulfills the intended SIS design specifications by providing participants with interactive functionalities necessary for performing real-time collaborations [3].

The UVC offers options such as audio/video recording, multimedia playback, and multi-touch drawing. These services are built upon the robust and integrated libraries belonging to Qt, cross-platform audio/video solution FFMPEG, and the image-processing library Open Computer Vision (OpenCV)[4][5][6].

Keywords: Ubiquitous Video Conferencing, Semantic Information System, Bandwidth Analysis, Project Collaboration, Audio Compression, Multithreading

1 Introduction

The trends of increasing computing power, affordability of hardware, and emergence of embedded networked systems have enabled businesses, researchers, and students the capability of accessing the information through technologies such as the Internet, technical software, and peer-to-peer communication.

Although web-browsers, social network applications, and voice/video communication enable users to indentify “birds of a feather” communities, information is often scattered among various networks often hindering the ability for information updates to be synchronized in a seamless fashion.

Semantic Information System platform is best suited for educators, researchers, and team-project members with common interest of information generation, analysis, interpretation, and dissemination. SIS users will be able to “objectize” information nodes of their projects, which will be generated in a hierarchical tree structure model to interrelate those nodes based on their semantic meaning and relationship with respect to each other. These user-generated contents can be accessed, updated, and shared with other network participants.

For the aforementioned SIS platform, a need for communication interface was born. In order for the project collaborators to interact with each other a Ubiquitous Video Conferencing (UVC) has been developed. It provides SIS users with real-time interactive application features.

The organizational flow of the paper is outlined as follows: The need for the SIS and its background are described within the Introduction section. It is followed by
the System Technologies implemented to comprise the SIS network. Then, the Application User Controls section describes the application interface and features of the UVC application itself. The last sections, Performance Analysis and Conclusion, present, discuss, and summarize experimental performance data obtained for real-time video and audio processing.

2 System Technologies

The key components that comprise the backbone of the Semantic Information System Network are Scraping Tool, PostgreSQL-based participant database, Qt API, and the UVC software.

The Scraping Tool is the application that has a mechanism for gathering content from network resources and populating its tree structure in a hierarchical manner. Figure 2 shows the 3D representation of such content structure. Through this data publishing process, SIS users can gather relevant content from various sources and store, or integrate them in a central location.

A PostgreSQL Relational Database Management System performs data warehouse storage allocation and unique key assignments to the content within the network. The database also keeps track of registered SIS users and stores their access privileges, which play an important role in system security. Qt API is an open-source development platform that is geared toward design of Graphical User Interface (GUI) applications with extensive set of modules and libraries available. To facilitate audio and video and perform multimedia compression, Open Computer Vision (OpenCV), FFmpeg, and Speex library tools were assembled to the application development project in order to create the Ubiquitous Video Conferencing application.

3 Application User Controls

UVC is intended for interactive communication over the Semantic Network, where conference participants are able to collaborate on their ongoing project via multimedia communication channels. To ensure well-organized project environment, it is necessary to grant certain member(s) session moderation privileges. In moderated sessions, an initiator of the videoconferencing is automatically assigned with Forum Coordinator regulatory privileges. When establishing a videoconference link, the Forum Coordinator of the group will initiate a session, thus relevant group members can join by authentication. Members will have their unique credentials and will be required to enter an additional verification code for a specific conferencing room. Its main GUI is displayed on Figure 3. Upon joining, members’ data such as the user name, IP address, application device capabilities (webcam/microphone/text chat only) will be logged in the “lookup table”. The Forum Coordinator will be in charge of placing and lifting restrictions on each participant such as who can use video/audio channels and when. Figure 4 displays UVC Voting System used during decision-making operations of real-time project collaboration.

Figure 2: 3D Visual Representation of the SIS

Figure 3: Main GUI of the UVC Application

Figure 4: Voting System of the UVC Application
4 Performance Analysis

4.1 Video

The Performance of Network utilization has been conducted to determine the network traffic due to various transmission rates of video and audio data. The three experiments have been performed in order to find the average ratio of the network usage compared to the maximum available traffic. The sender is able to vary the FPS (frames per second) rate and hence, impact on the availability of network resources. This feature of real-time frame rate control assists to the application users in determining the appropriate frame rate settings during videoconferencing sessions. Users are able to free up their network resources by lowering their transmission frame rates. Oppositely, they can improve quality of their transmitted video data sacrificing more bandwidth. This tradeoff allows for real-time network resource management by the application participants. The default frame-rate setting has been set to 7fps, which on average takes 5.95% of the Network Resources over IEEE 802.11g -54 Mbps network connection. In order to avoid system instability, no more than seven participants of the same network, should be broadcasting their video at that frame rate. In order to accommodate more video streams, participants must lower their transmission frame rate.

4.2 Audio

This section presents and discusses the experiments performed to analyze the integration of audio transmission within the UVC application. The video and audio channels run in a multithreading environment, with each channel having a dedicated processing thread. The UVC application provides its participants with direct multimedia channel control, where system participants are able to close and (re)-open video and/or audio channel streams with individual participants. The UVC GUI has various options that provide users with an easy and efficient control panel. Audio Codec selection is the primary audio bandwidth regulator that UVC offers to the end user. A participant may choose from the three following types of audio transmission: Pulse-Code Modulation (PCM) Raw audio streaming, Zlib codec and Speex audio codec [7] [8]. The experiments on audio performance were done over IEEE 802.11g -54 Mbps network connection. The experiments were conducted to determine the compression ratios of Zlib and Speex codec to the Raw PCM data. They are shown in Figure 3.

![Codec Type Compression Ratio to Raw PCM Data](image)

Table 1: Processing Time of UVC Audio Transmissions

<table>
<thead>
<tr>
<th>Codec Type</th>
<th>Processing Time per 1000 cycles</th>
<th>Processing Time per 1000 cycles</th>
<th>Processing Time per 1000 cycles</th>
<th>Ave. Time per cycle (ms)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Exp. 1 (ms)</td>
<td>Exp. 2 (ms)</td>
<td>Exp. 3 (ms)</td>
<td></td>
</tr>
<tr>
<td>Raw PCM</td>
<td>38823</td>
<td>38700</td>
<td>38625</td>
<td>38</td>
</tr>
<tr>
<td>Zlib</td>
<td>38241</td>
<td>38299</td>
<td>38265</td>
<td>38</td>
</tr>
<tr>
<td>Speex</td>
<td>38518</td>
<td>38587</td>
<td>38605</td>
<td>38</td>
</tr>
</tbody>
</table>

Table 2 shows three bandwidth measurements of aforementioned audio codecs with a constant video feed of 25 FPS. These average values have been also obtained for a 54Mbps Wireless Network.
Table 2: Bandwidth of single Audio and Video stream

<table>
<thead>
<tr>
<th>Codec Type</th>
<th>Network Utilization Exp. 1 %</th>
<th>Network Utilization Exp. 2 %</th>
<th>Network Utilization Exp. 3 %</th>
<th>Average Network Utilization %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw PCM</td>
<td>19.30</td>
<td>19.35</td>
<td>19.31</td>
<td>19.32</td>
</tr>
<tr>
<td>Speex</td>
<td>19.09</td>
<td>19.08</td>
<td>19.08</td>
<td>19.08</td>
</tr>
</tbody>
</table>

5 Conclusion

This paper focused on analyzing performance characteristics of the interactive functionalities within the Ubiquitous Video Conferencing application. The real-time optimization of video and audio data offers multiple configurations to the SIS collaborators in terms of adjusting their transmission and receiving parameters. These configuration options provide flexibility for bandwidth control, as the participants can regulate their network bandwidth in order to raise the multimedia quality, or increase participating session capacity. The multithreading nature of the application provides dedicated transmission of individual audio and video channels. The performance characteristics obtained from the bandwidth analysis demonstrated the strength of the application’s real-time configurability and flexibility. During project collaborations over the SIS platform, users are given the tools to self-regulate the scalability of the rapidly varying videoconferencing session environment.

6 References

[8] Speex - an Open Source/Free Software patent-free audio compression format designed for speech <http://www.speex.org>