A REAL-TIME HIGH-RESOLUTION UNDERWATER ECOLOGICAL OBSERVATION STREAMING SYSTEM

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ABSTRACT:

This paper proposes a distributed architecture for real-time high-resolution underwater ecological observation streaming. The system, based on a three-tier architecture, includes stream receiver unit, stream processor unit, and presentation unit. It is a distributed computing and a loose coupling architecture. Stream receiver unit supports a variety of capture source devices, such as HDV, DV, WebCam, TV Card, Capture Card, etc., and stream compress encoding formats, such as MPEG-1/2/4, FLV, WMV, MJPEG, etc., that are commonly used. The multiple format supported feature made our system an outstanding platform, on which streaming can easily be broadcasted in real-time. Stream processor unit has two options: one directly streaming to presentation unit, the other to slices streaming into sequence of images and can be extracted and stored for further implement image processing. Presentation unit supports multiple display devices handy to end users. A web-based user interface was designed to allow users to select multiple real-time streams to browse.

The system has been demonstrated to ecological observation in Taiwan. Ken-Ting National Park is located on the southernmost tip of Taiwan and is known for its dazzling coral reef. Four underwater CCTV cameras and three underwater high-resolution cameras are deployed to monitor the ecosystem of coral reefs continually and videos captured are streamed and processed in real-time. For HDV cameras, the challenges are network bandwidth and decode a high-resolution stream in real-time. The distributed servers are putted on NMMBA (National Museum of Marine Biology and Aquarium), and streams are transferred back to NCHC's (National Center for High-performance Computing) multicasting pool. Experimental results showed that the proposed distributed system is robust, adaptive, and powerful.

Google Earth is a virtual globe and geographic program. It displays satellite images of varying resolution of the Earth's surface, and users can see the details, such as cities and streets, on Earth. Due to the powerful functions and population of Google Earth, we integrated our streaming system on Google Earth. Users can browse the real-time streaming and the surrounding environment on Google Earth.

1. INTRODUCTION

Environmental challenges include invasive species, infectious diseases, climate and land-use change. Environmental observing science is undergoing dramatic changes through revolutions in information and other technologies including sensor networks and grid computing. Environmental science and engineering communities are now actively engaged in the early planning and development phases of the next generation of large-scale sensor-based observing systems. In all of these systems, streaming data has a central role (Strandell, 2007).

Nowadays, network technology has been advancing dramatically since the invention of the Internet. The network applications tied up with our daily life, such as VoIP, distance learning, mobile phone, GPS navigation, etc. Video streaming over internet is a hot topic recently. The basic concept is to send recordings through the Internet and users can browse them in any place at any time where network is available. Streaming can also broadcast live events from a server, over the Internet, to end users. In recent years, owing to the advance of streaming technology and the booming of network bandwidth, live video streaming is getting more and more popular.

In this paper, we developed a distributed real-time streaming system, which allows users to switch capture devices required no extra software installation efforts, and to browse video streams on any display devices as users want. The distributed streaming system is applied to real-time high-resolution underwater ecological observation. Four CCTV cameras and three HDV cameras are set up in Ken-Ting, Taiwan, and pass the distributed streaming system to facilitate marine ecologists to closely monitor the ecosystem of coral reefs.

This paper is organized as follows: Section 2 describes distributed system architecture details. Real-time streaming cases studies are presented in Section 3, followed by the conclusions in Section 4.

2. DISTRIBUTED SYSTEM ARCHITECTURE

In the paper, a distributed streaming system is developed. The distributed streaming system for real-time high-resolution streaming is loose coupling and three-tier architectures, includes stream receiving unit, stream processing unit, and presentation unit (Chou, 2009). Figure 1 illustrates the distributed streaming system architecture and stream pipeline.

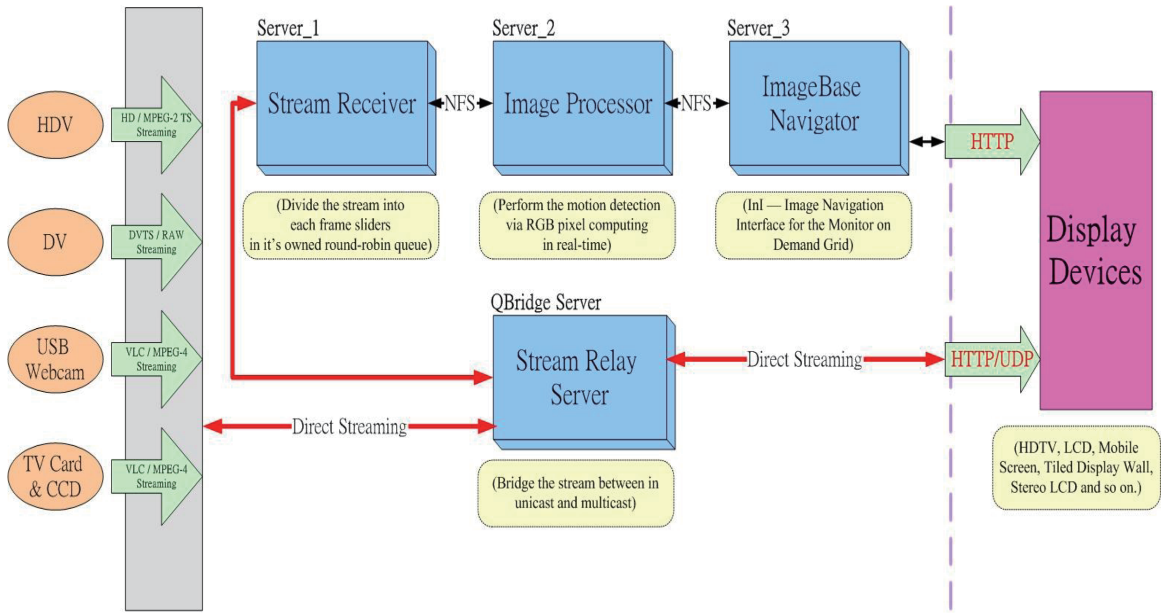


Figure 1. Architecture blocks and stream pipeline

2.1 Distributed System Architecture

In stream receiving unit, it supports multiple capture devices and automatically identifies these devices and chooses a proper encoder correspondingly. It created a device identification module, packed together with several commonly used software components into one package. The common use devices, such as HDV, DV, DC, Webcam, TV Card and Capture Card, and multiple stream compress encoder formats, such as MPEG-1/2/4, WMV, FLV, MJPEG, are supported in stream receiving unit. The benefit is it doesn't have to bind the specific hardware devices any more.
In stream processing unit, there are two options after stream received: one directly streaming to presentation unit, the other to slices it into sequence of images and can be extracted and stored for further implement image processing. In the second option, these images are put in the respective round robin queues, and are convenient to implement some image processing methods, such as event detection, object tracking, image segmentation. After finishing the image processing methods, these images and relative log information are automatically stored in the image database. By passing the image management server, users can query, browse, analyze, and manage these images.
In presentation unit, it supports multiple display devices handy to end users. The easiest way for users to view the streams is to use web browser. A web-based user interface is designed to allow users to select multiple real-time streams to browse. Figure 2 illustrates the web-based user interface. For advance users, a 4x3 Tiled Display Wall (TDW for short), a versatile, large, and high-resolution display system that was constructed by National Center for High-Performance Computing (NCHC for short), Taiwan, are used (Lin, 2005). Figure 3 illustrates the TDW presentation platform.

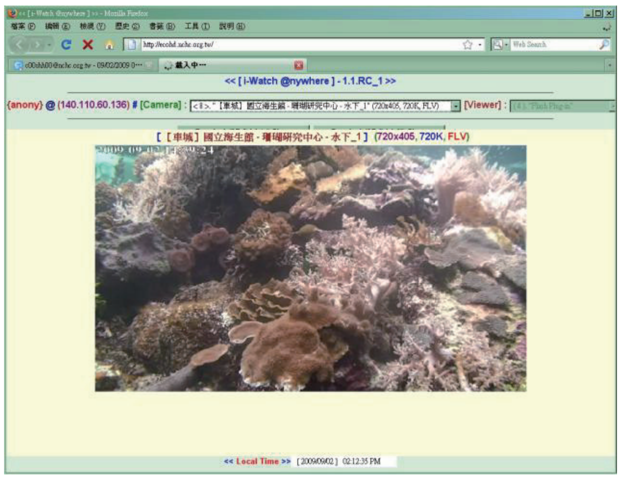


Figure 2. A web interface for stream viewing, users can select multiple real-time streams from top panel

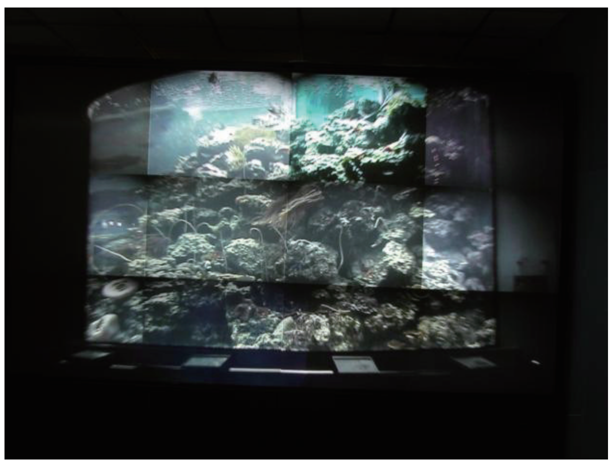


Figure 3. TDW presentation platform

2.2 Distributed Stream Compression Methods

In order to reduce the network transfer flow, two distributed video stream compression concepts are implemented to advance the streaming efficiency. The first distributed compression is client-server based concept. It includes pre-compression in the client site and post-compression in the server site. Stream receiving unit receives video streaming from the client site and implements pre-compression to reduce the network flow. The post-compress transfers the original video streaming data to multi-formats, such as MPEG-1/2/4, WMV, FLV and MJPEG, to reduce the data capacity (Nguyen, 2004; Traiperm, 2005).

The second distributed compression is server-side based concept. It is implemented to dynamically assign the video streaming to the suitable servers depending on the loading of the servers. It compresses the video stream to a variety of bit-rates for different network bandwidth requirements. A real-time high-resolution streaming system is implemented by using these two distributed stream compression concepts. Figure 4 illustrates the comparison with/without using these two compression concepts to transfer video streaming. The top image is the native MPEG-2 bit-rates and the bottom image is the compressed MPEG-2 bit-rates. The compressed ratio is almost 25 times using these two compression methods.

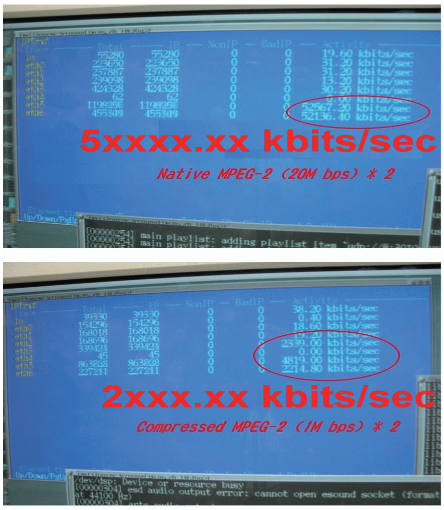


Figure 4. Illustration of the bandwidth with/without distributed stream compression concepts.

2.3 Storage Resource Broker

The management of real-time video streaming data in large-scale collaborative applications presents major processing, communication and administrative challenges. To preserve these video streaming data in a long term requires huge amounts of storage spaces. Video streaming data sets from observation sites were archived into storage pool on a daily basis, and a backup replication in second storage pool was created by the function Storage Resource Broker (SRB) (Nakajima, 2005; Tilak, 2007), developed at San Diego Supercomputer Center (SDSC for short). The SRB supports shared collection that can be distributed across multiple organization and heterogeneous storage systems. It is a data grid middleware that provides a hierarchical logical namespace to manage the organization of data. We adapted SRB to presents applications with a single file hierarchy for data scattered across multiple disk spaces. This system also allows for new storage resources to be added dynamically. Schematic view of stream servers and storage pool implementation is described in Figure 5.

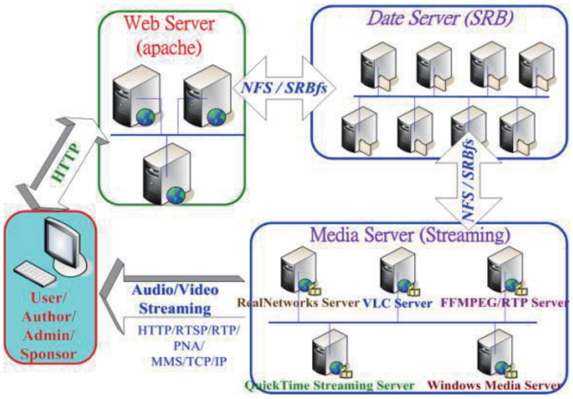


Figure 5. Illustration of the schematic view of stream servers, and storage pool

3. IMPLEMENT RESULTS

Some cases were implemented to test the above-mentioned distributed streaming system. It is briefly introduced as followed.

3.1 Long Term Underwater Ecological Observation

Ken-Ting National Park (KTNP for short) is located on the southernmost tip of Taiwan and is known for its dazzling coral reef. The ecological observatory in Ken-Ting includes a total of four underwater CCTV cameras with resolution of 640x480 facilitates marine ecologists to closely monitor the ecosystem of coral reefs. There is a video server that converts analog video signals into digital video streams. The video server is installed within a steel casing located on the shore. Figure 6 illustrates the underwater video cameras and the video server.

Video streams are sent to a local monitoring station and then redirected to our system. The system watches closely to the ecosystem of coral reef habitat, sending and recording images 24 hours a day. These continuous recordings can help marine ecologists in elucidating the ecological processes that primarily involve slow processes, rare events, and high temporal variability at the study sites. In addition, such a real-time streaming observation scheme may enhance public's awareness of marine conservation. Figure 7 illustrates the coral reef underwater observation streams. The left side is the four CCTV cameras and the right side is the water temperature.

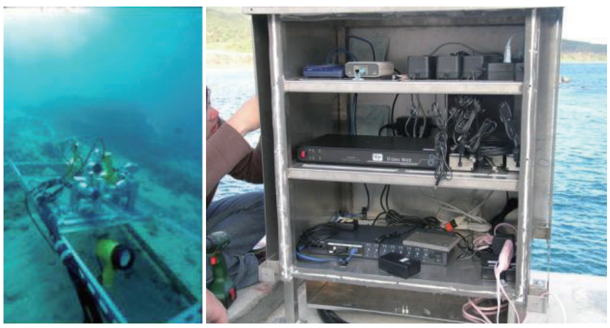


Figure 6. Illustration of the underwater video cameras and the video server

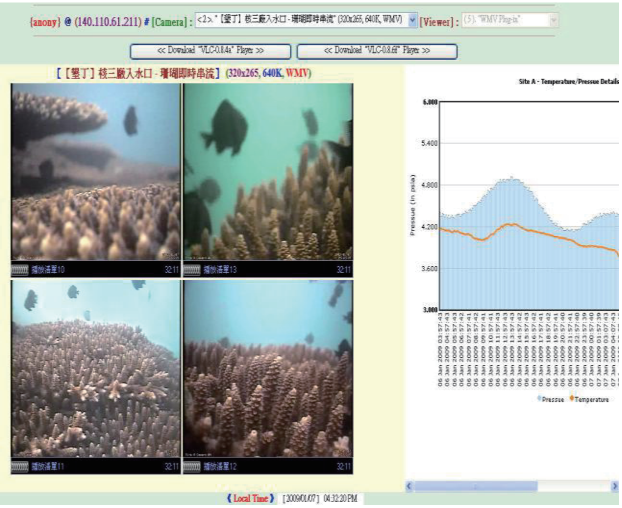
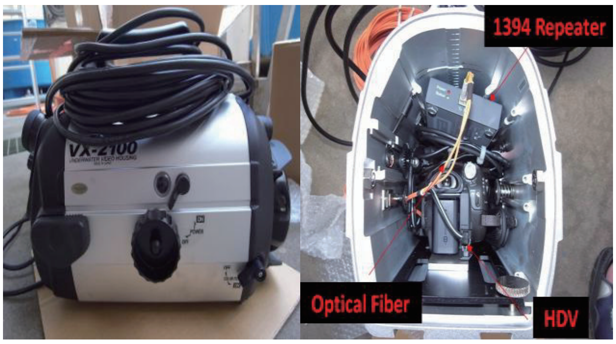


Figure 7. Illustration of the Coral reef underwater observation

3.2 High Resolution Underwater Ecological Observation

National Museum of Marine Biology and Aquarium (NMMBA) in Taiwan is an institution dedicated to public education and research of marine biology. Besides aquarium exhibitions, the museum also aims for survey, collection, preservation and study of marine organisms around Taiwan. The ecological observatory in NMMBA includes a total of three underwater HDV cameras located on three different sites inside a fairly large lagoon. In order to provide higher resolution, we set up an experimental system using HDV camera with resolution of 1280x1080 to broadcast the real-time coral reef observation over the Internet. One challenge is how to protect the HDV camera underwater for a long time. We set up a waterproof case to protect the HDV, 1394 repeater and optical fiber. Figure 8 (a) shows the waterproof case and (b) shows the HDV, 1394 repeater and optical fiber inside the waterproof case. The other challenges of this experiment are network bandwidth and to decode a high resolution streaming in real-time. Our test was successful with only a few seconds latency. Figure 9 illustrates the high-resolution underwater ecological streaming with MPEG-2 format. Figure 10 illustrates the high-resolution underwater ecological streaming with FLV format. Figure 11 illustrates the high-resolution underwater ecological streaming with WMV format.



(a) (b)

Figure 8. (a) The waterproof case, (b) HDV, 1394 repeater and optical fiber

Figure 9. Illustration of the high-resolution underwater ecological streaming with MPEG-2 format

Figure 10. Illustration of the high-resolution underwater ecological streaming with FLV format

Figure 11. Illustration of the high-resolution underwater ecological streaming with WMV format

3.3 Ecological Observation on Google Earth

Google Earth is a virtual global, map and geographic information program. It displays satellite images of varying resolution of the Earth's surface, allowing users to see things like cities and houses. The Google Earth API is a free service, available for any web site that is free to consumers. The Plug-in and its JavaScript API allow users to place a version of Google Earth into web pages. In this paper, we integrated our real-time streaming system on Google Earth. Users can browse the real-time streaming and the surrounding environment on Google Earth. Figure 12 shows the CCTV camera streaming on Google Earth. Figure 13 shows the high-resolution streaming on Google Earth.

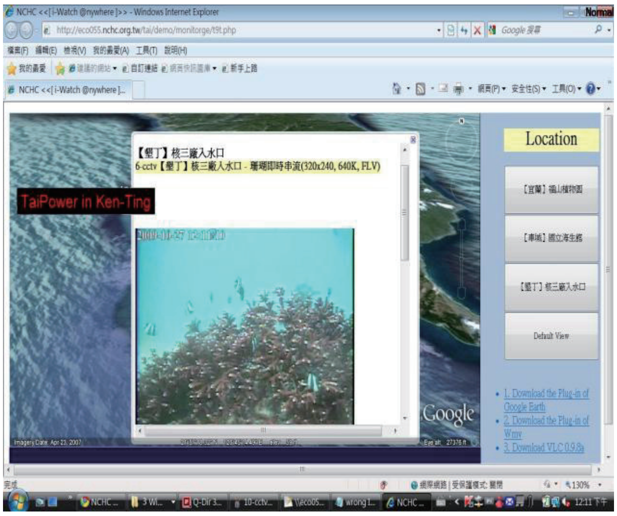


Figure 12. Illustration of the CCTV camera streaming on Google Earth

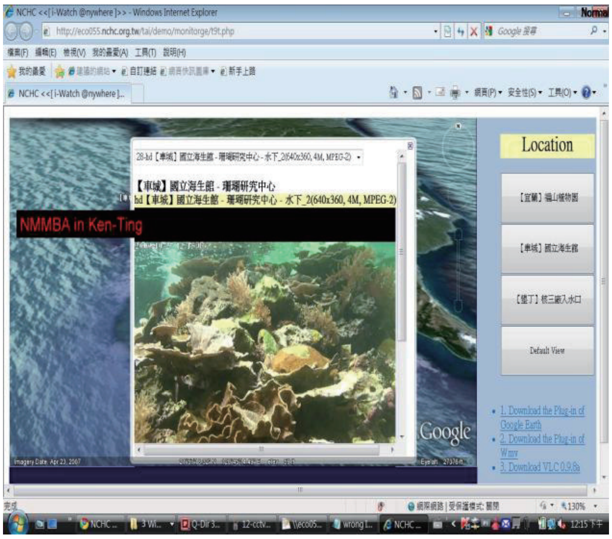


Figure 13. Illustration of the high-resolution streaming on Google Earth

4. CONCLUSIONS

This paper proposes a distributed architecture for real-time high-resolution underwater ecological observation streaming. The system has been demonstrated to ecological observation in KTNP and NMMBA, Taiwan. We set up an experimental system using four CCTV cameras with resolution of 640x480 and three HDV cameras with resolution of 1280x1080 to broadcast the real-time underwater streaming over the Internet. The distributed servers are located on KTNP and NMMBA, and streams are transferred back to NCHC's multicasting pool for real-time observation. Experimental results showed that the proposed distributed streaming system is robust, adaptive, and powerful.

For HDV cameras, the challenges are network bandwidth and decode a high-resolution streaming in real-time. Two distributed streaming compression concepts are implemented, and our system has been proofed successful in real-time ecological observation with resolution up to 1280x1080. Yet, many applications, such as medical imaging, require seeing more details. In the future, we will explore further to the distributed real-time streaming concepts frontier with the goal to instantly deliver high quality videos to end users.

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