Inter-Stream Synchronization Control with Group Synchronization Algorithm

Hiroya Sannomiya, Junya Osada, Yutaka Ishibashi, Norishige Fukushima, and Shinji Sugawara
Graduate School of Engineering, Nagoya Institute of Technology, Japan

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Outline

- Background
- Purpose
- Proposal of Inter-Stream Synchronization Control
- Experiment Method
- Experiment Results
- Conclusions and Future Work
The efficiency of remote work over a network can greatly be improved by using haptic media and other media streams together.

Transmission of haptic media and other media streams in a network

- Network delay
- Delay jitter

The temporal relationships among the media streams are disturbed.

The quality of service (QoS) of the streams may seriously be degraded.

We need to carry out media synchronization control.
Intra-stream synchronization control preserves the timing relation in a single stream.

Inter-stream synchronization control keeps the temporal relationship among multiple streams.

Group synchronization control adjusts the output timing of a media stream among multiple destinations.
VTR (Virtual-Time Rendering) algorithm* for intra-stream and inter-stream synchronization control

- One of multiple media streams which should be synchronized is selected as a master stream, and the others are slave streams.
- Only intra-stream synchronization control is carried out over the master stream, and intra-stream and inter-stream synchronization control is performed over each slave stream.
- Each slave stream is output in synchronization with the master stream.

Problem

The intra-stream synchronization quality of each slave stream may largely be degraded by the inter-stream synchronization control.
We propose inter-stream synchronization control which uses a group synchronization algorithm, which adjusts the output timings of the master streams at all the destinations to each other.

The main idea of the proposed control is to deal with all the streams which should be synchronized as master streams.

We can achieve inter-stream synchronization among all the streams by using the group synchronization algorithm.
The proposed inter-stream synchronization control can attain high quality of intra-stream synchronization of multiple media streams by allowing inter-stream synchronization errors among the media streams to some extent.

We implement the proposed control in a remote control system with haptic media and video and investigate the behavior of the control by experiment.
The distributed control scheme* is used for the group synchronization algorithm.

- The scheme is used with the VTR algorithm, which is employed for intra-stream and inter-stream synchronization control.
- Each destination transmits information about the output timing of the master stream at the destination to the other destinations when the destination starts to output the master stream and when the output timing is changed by the VTR algorithm.
- The destination determines the reference output timing by using the output timing of the master stream at the destination and those received from the other destinations. Then, it gradually adjusts the output timing of the master stream to the reference output timing.

Two ranges are used: The *imperceptible range* and *operation range*.

- The imperceptible range is a range of inter-stream synchronization error which almost all persons do not notice.
- The operation range is a range of the error which should be kept usually and is narrower than the imperceptible range for safety.

![Diagram showing imperceptible range and operation range](image)
Proposed Inter-Stream Synchronization Control (2/3)

At the beginning of media output

- If the inter-stream synchronization error is outside of the operation range, we try to modify the output timing gradually so that the error enters the operation range by changing the reference output timing, which is decided by the group synchronization algorithm.
- Otherwise, we employ the current output timing as the reference output timing.
Proposed Inter-Stream Synchronization Control (3/3)

After the beginning of media output

- If the inter-stream synchronization error goes out of the imperceptible range when the output timing is changed by the VTR algorithm, we try to modify the output timing gradually so that the error enters the operation range.

- Otherwise, we employ the current output timing as the reference output timing.

![Diagram showing the concept of imperceptible and operation ranges for inter-stream synchronization error.](image-url)
Experimental System

An additional delay for each packet is generated according to the Pareto-normal distribution.

MU: Media unit information unit for media synchronization

Transport protocol: UDP

Remote control system with haptic media and video
**Work:** Trace the surface of tennis ball*

- Imperceptible range: $-40 \text{ ms} \sim 100 \text{ ms}$
- Operation range: $-40 \text{ ms} \sim 50 \text{ ms}$
- We carried out three types of experiments (experiments 1, 2, and 3).

In experiment 2, the inter-stream synchronization error is larger than the upper limit of operation range ($= 50 \text{ ms}$) when the media output is started.

<table>
<thead>
<tr>
<th>Media</th>
<th>Video</th>
<th>Haptic media</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average additional delay [ms]</td>
<td>60</td>
<td>10</td>
</tr>
<tr>
<td>Standard deviation of additional delay [ms]</td>
<td>10</td>
<td>5</td>
</tr>
</tbody>
</table>
Experiment Results (1/2)

- Output timing of video: 77 ms ( = 60 ms + 7 ms + 10 ms)
- Output timing of haptic media: 16 ms ( = 10 ms + 1 ms + 5 ms)

Inter-stream synchronization error: 61 ms ( = 77 ms - 16 ms)

- The error ( = 61 ms) is larger than the upper limit of operation range ( = 50 ms).
- The reference output timing of haptic media is set to 27 ms (77 ms - 50 ms).

※ We cannot change the output timing of video because we cannot advance the output time up to the arrival time plus the initial buffering time.
※ The output timing of haptic media ( = 27 ms) is smaller than the maximum value of the output timing ( = 60 ms).

The output timing of haptic media is gradually delayed up to 27 ms so that the error enters the operation range ( = 50 ms).

MU: Media unit
Information unit for media synchronization

Processing time
Initial buffering time
Processing time
Initial buffering time
Processing time
Initial buffering time
Processing time
Initial buffering time
Processing time
Initial buffering time

The output timing is denoted by the time interval from the moment an MU is generated until the instant the MU is output.
The target output time denotes the time when an MU should be output in the case where the network delay jitter exists.

The output timing of haptic media is delayed by 5 ms under the proposed control.

Experiment Results (2/2)
Conclusions

- We proposed inter-stream synchronization control by using a group synchronization algorithm to achieve high quality of intra-stream and inter-stream synchronization.
- We examined the behavior of the proposed control with haptic media and video.
- We confirmed that the proposed control behaves properly at a high level of quality.
Future Work

- We will make a comparison between the proposed control and conventional control subjectively.