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An Improvement of Service Qualities by Edge Computing in Network-oriented Mixed Reality Application

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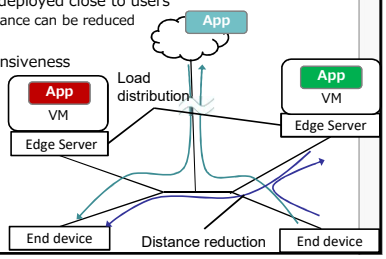
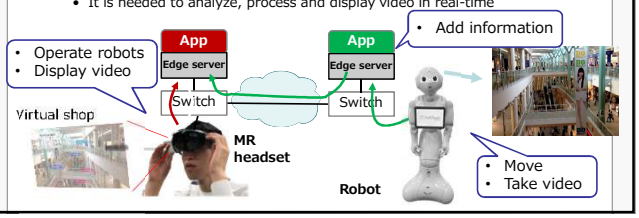
Introduction

- **Latency in cloud computing environment**
  - Long communication distance
  - Load concentration
- **Expectation for edge computing (MEC)**
  - Multiple edge servers are deployed close to users
    - Long communication distance can be reduced
    - Load can be distributed
  - Improve application responsiveness



Service Application for MEC

- **Telexistence service**
  - Users monitor robots in remote area from home as if they were there
- **Network-oriented service using MR (Mixed Reality)**
  - Information is added to the video
  - Users operate robots with their gestures
  - MR applications require low latency
    - It is needed to analyze, process and display video in real-time

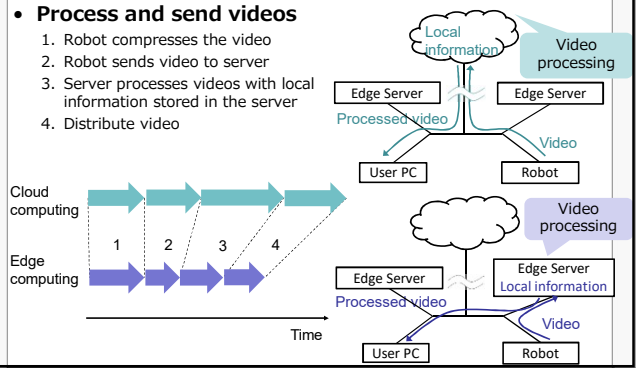


Research Purpose and Approach

- **Research purpose**
  - Investigate tolerable latency in network-oriented MR applications
  - Examine the improvement of service quality by edge computing for network-oriented MR applications
- **Approach**
  - Develop a network-oriented MR application
    - A user operates a remote robot through user's gestures
    - The remote robot sends videos to the user
  - Introduce edge computing
  - Experiment with subjects
    - Set 4 simple tasks
    - Emulate network delay that will occur in cloud computing environment
    - Measure task completion time under each condition
    - Evaluate service qualities

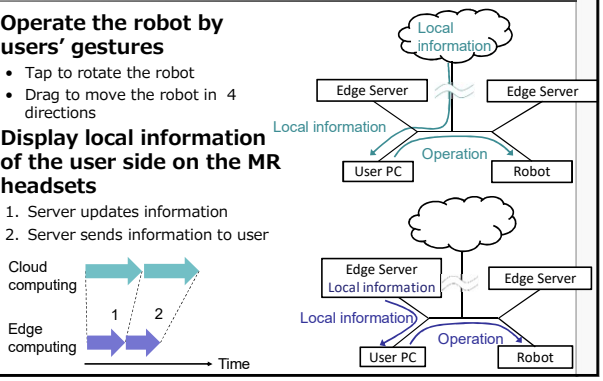
MR Application: Robot side

- **Process and send videos**
  1. Robot compresses the video
  2. Robot sends video to server
  3. Server processes videos with local information stored in the server
  4. Distribute video



MR Application: User side

- **Operate the robot by users' gestures**
  - Tap to rotate the robot
  - Drag to move the robot in 4 directions
- **Display local information of the user side on the MR headsets**
  1. Server updates information
  2. Server sends information to user



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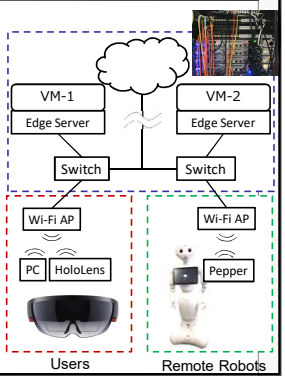
Experiment Environment

- **Microsoft HoloLens, PC, Pepper are connected**
- **Emulate network delay that will occur in cloud computing environment at VMs**
- **About 420 [ms] additional delay in Pepper[15]**
  - It takes 420 [ms] for Pepper to convert video to mpeg format



[15] Junichi Kaneda, Shin'ichi Arakawa, and Masayuki Murata, "Effects of Service Function Relocation on Application-level Delay in Multi-access Edge Computing," *in Proceedings of IEEE 5G World Forum*, July 2018.

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Experiment Method

- **Preliminary experiment**
  - We operate each tasks with 0 [ms], 100 [ms], ⋯, 500 [ms] network delay
  - 420 [ms] to 920 [ms] delay between User PC and Pepper
    - Because it takes 420 [ms] to compress the video
- **Main experiment**
  - 8 participants operated 4 tasks twice
    - We divided 8 participants into 2 groups of 4 people

Main experiment

Group	1st operation	2nd operation
1	With no delay	With 300+420 [ms] delay
2	With no delay	With 500+420 [ms] delay

Tasks

Task	Information	Operation
1	None	move to the goal given beforehand
2	User side	move to the goal shown in MR headset
3	Robot side	move to the goal shown in video
4	Both	move to the goal shown in local information

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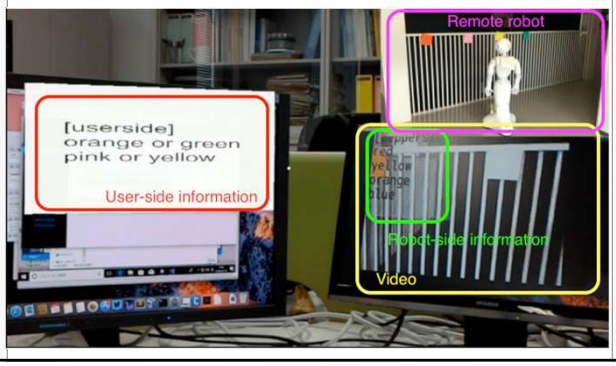
Demonstration



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Evaluation Method of Service Qualities

- **Objective evaluation**
  - Measure task completion time under each condition
  - Compare task completion time
- **Subjective evaluation**
  - Participants evaluated the quality of second operations (with 300 [ms] or 500 [ms] network delay) compared with first operations (with no network delay) , with the categories shown in the table
  - We calculated MOS (Mean Opinion Score)
  - Evaluation items
    - E1: Quality of the video from the robot
    - E2: Comfort of robot operation
    - E3: Immersion etc.

Category	Score
Much better	3
Better	2
Slightly better	1
About the same	0
Slightly worse	-1
Worse	-2
Much worse	-3

[16] International Telecommunication Union, "Recommendation ITU-T P.800, Methods for subjective determination of transmission quality."

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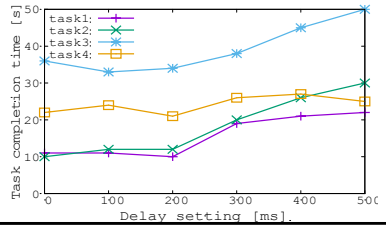
Results: Task Completion Time

- **Result of the preliminary experiment**
  - Similar results in this experiment
- **Nonlinearity of the task completion time to network delay was not observed**
  - There was no puzzlement or operation error due to delay of the video because tasks given to subjects were simple and subjects predicted the delay



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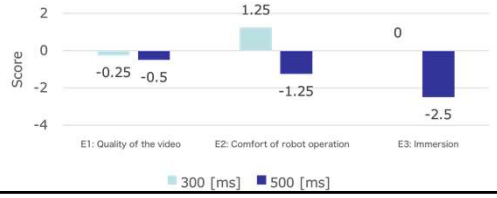
Results: Subjective Evaluation

- **Quality drops suddenly when network delay exceeds a certain value between 300 [ms] and 500 [ms]**
  - From 720 [ms] to 920 [ms] between User PC and Pepper
  - Service quality suddenly gets worse when application latency becomes around 1 [sec]
  - Need to understand the human experience mechanism in detail
    - It is not easy to estimate service quality of their services only with objective indicators



Conclusion and Future Work

- **Conclusion**
  - We developed a network-oriented MR application
  - We performed an experiment with 8 subjects
  - Service quality suddenly gets worse when application latency becomes around 1 [sec]
- **Future Work**
  - Performing experiments by randomly generating network delay
  - Performing experiments with more subjects