

R&D Theme

Development of a CA which has a humanlike presence and a lifelikeness

Progress until FY2022

1. Outline of the project

In this R&D theme, our goal is to develop cybernetic avatars (CAs) with humanlike appearance, functionality, and lifelike characteristics. Additionally, we will create mobile CAs with childlike features that can extend their presence and lifelikeness by being able to move freely in the environment. Furthermore, an automatic motion generation system will express the teleoperator's intentions, emotions, and personality through CAs. An immersive interface will provide operators with free control over the CAs. Through these R&D efforts, CAs will serve as substitutes or avatars for teleoperators in social situations, overcoming spatial and temporal constraints. It will enable us to effectively accomplish and excel in tasks that require simultaneous presence at multiple locations.

2. Outcome so far

1. We designed and implemented expressive gestures into the CA to enable it to interact with users through appropriate body movements and facial expressions based on the dialogue partner and content.

This implementation allows the CA to perform fluent and beautiful gestures, particularly in situations where it is crucial to appeal to the dialogue partner, such as during presentations. As a result, the CA now exhibits more expressive and hospitable behavior than the operator themselves (Figure 1).



Figure 1: CA which has a humanlike presence, exhibiting more expressive gestures than the operator themselves

2. We developed a CA for the Minister of the Digital Agency (Figure 2) and conducted a field experiment in which the Minister provided official services by remotely operating the CA. The Minister controlled the CA installed at a commercial facility and offered official services, such as explaining the initiatives of the Digital Agency to passers-by. During this field experiment, we conducted a survey on the social acceptability of CA use by individuals with significant influence.



Figure 2: Digital Agency Minister's CA and the Minister himself

3. We have developed CAs with lifelikeness by making their moving mechanism silent. It has been confirmed that these silent CAs are perceived as having more agency compared to CAs with motor sound. Additionally, we have created a life-like CA equipped with an organic EL display on its face. This CA can freely alter its facial expressions, allowing for a more diverse expression of personality.



Figure 3: Mobile life-like CA

4. By employing inverse reinforcement learning, the avatar has acquired the skill to recognize the optimal moments to request disinfection, surpassing the perceptual abilities of typical individuals. It contributed to the overall goal of expanding the capabilities of the operator.



Figure 3: CA asking for disinfection at a shopping mall

3. Future plans

The CA to be developed under this R&D theme will free the operator from physical, spatial, and temporal constraints by taking their place. Furthermore, we aim to develop CAs with functions and capabilities that go beyond mere substitution for humans. Through such CAs, we will not only be able to work in different places and at different times, but we will also be able to demonstrate abilities and behaviors that we would not normally be able to do.

R&D Theme

Research and development on unconstrained spoken dialogue

Progress until FY2022

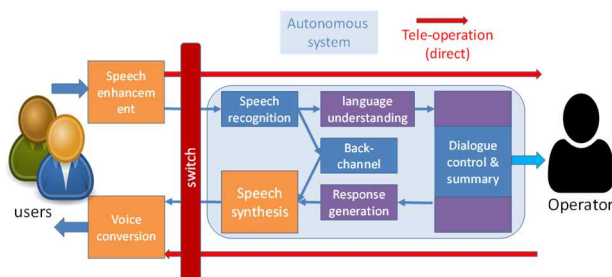
1. Outline of the project

We investigate automatic speech recognition and dialogue technologies to realize an autonomous spoken dialogue system with human-like hospitality, and develop flexible framework that allows the avatar to seamlessly switch between remote control dialogue and autonomous dialogue according to the operator's intentions and situation.

Thus, this group is responsible for the spoken language dialogue processing in this project. Spoken dialogue systems have been put to practical use in smart speakers and chatbots, but they are limited to uniform knowledge-level exchanges. To achieve human-like long and deep dialogues, it is essential to understand the user's situation (including inside and outside the dialogues) as well as to generate natural backchannels and empathetic responses.

2. Outcome so far

- Speech processing.



- (1) Real-time speech separation and recognition under real noisy environments are realized.
- (2) Low-latency speech synthesis with emotional expression

and high naturalness is realized. **The research team won the first prize in the Voice MOS Challenge in Interspeech 2022.**

- (3) We investigate a robot that generates backchannels and laughter in sync with the user. **This work has been covered by major world-wide media including BBC and Guardian, and selected as one of the best innovations in 2022 by the major French media.**

Scientists try to teach robot to laugh at the right time

Research team hopes system could improve natural conversations between humans and AI systems



- Natural language and dialogue processing.
- (1) We constructed the largest-scale dialogue data with persona information and the task corpus in Japanese.
 - (2) We designed highly naturalistic CG avatars and built a software environment that can operate both autonomously and remotely.
- Integrated system

- (1) We have developed a system that conducts attentive listening for three people in parallel and simultaneously.
- (2) We have built a system that provides explanations and guidance to three people simultaneously and in parallel. It was used for a field trial at an aquarium for one month.



3. Future plans

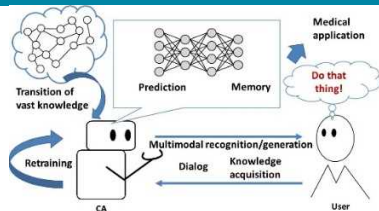
The individual modules of speech processing and dialogue processing have been developed to be deployed in the integrated system. We will test the system with subject experiments and field trials to feedback to the individual modules. We will also design more complex application scenario such as multi-party conversations, and develop the individual modules and the system.

R&D Theme

Human level knowledge and concept acquisition

Progress until FY2022

1. Outline of the project



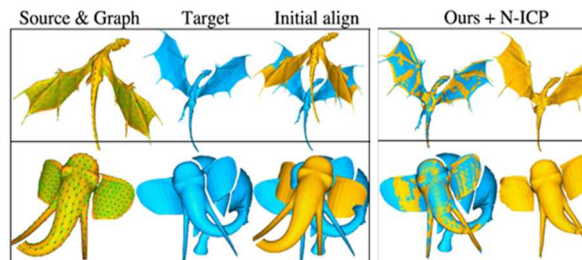
In this project, we work on the acquisition of human knowledge and concepts necessary for advanced cognitive abilities, knowledge sharing among cybernetic avatars (CAs), and understanding of the operator's intentions to realize semi-autonomous functions for cybernetic avatars (CAs) that move according to the user's intentions.

This knowledge and concept acquisition requires combining visual information with human-level knowledge and concepts and information from different modalities, including natural language. We also aim for CAs to acquire knowledge and concepts that can be shared with humans through the fusion of different modalities, such as visual information and natural language, and the realization of dialogues for knowledge sharing and acquisition in various real-world environments. Furthermore, observations and dialogues based on the acquired knowledge and concepts are used to understand the intentions of operators and users. Since it is difficult to control the environment for interactions between CA, operators, and users, and since the amount of data obtained is small, we will develop a new method for learning with a small amount of data to acquire new knowledge and concepts.

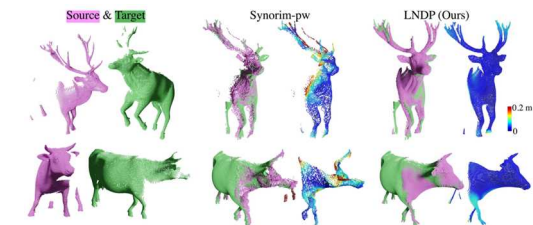
2. Outcome so far

In order for CA to share knowledge and interact with humans, it is essential to understand not only the real world semantically, but also the underlying geometry. In particular, geometrical understanding requires spatio-temporal modelling, including non-rigid objects that change shape over time. The object deforms drastically from moment to moment, and the point cloud representing the observed appearance and depth varies greatly, even if the object is the same. To solve this problem, we worked on matching and registration problems between point clouds of partial observations with large deformations and a free-form deformation method for radiance fields.

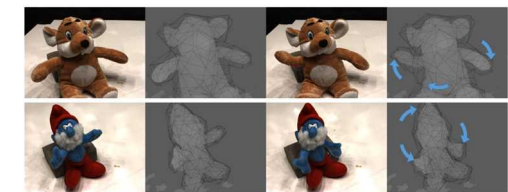
For partial point cloud matching in rigid and deformed scenes, we propose a learning-based method. The features of our method are a position encoding technique that separates the point cloud representation into a feature space and a three-dimensional position space to represent relative distance information, and a repositioning technique that changes the relative positions between point clouds. Our proposed method achieves twice the reproducibility of non-rigid feature matching compared to previous studies on a particularly challenging dataset for non-rigid point cloud matching. Our work has been accepted for oral presentation at CVPR2022.



In addition to partial point cloud matching, a study of non-rigid point cloud registration was also conducted. Non-rigid point cloud registration is challenging due to the high complexity of the unknown non-rigid motion. In this study, we solved this problem by using hierarchical motion decomposition. The hierarchical motion representation allows a multi-step decomposition from rigid-body to non-rigid-body motion, which leads to higher accuracy and speeds up the solution by a factor of 50 compared to existing neural network-based approaches. The work has been accepted for NeurIPS2022.



Furthermore, we proposed a new method to deform the radiance field: free-form deformation of the luminance field. This method uses a triangular mesh surrounding a foreground object, called a cage, as an interface and allows free-form deformation of the radiance field by manipulating the vertices of the cage. This work has been accepted for ECCV2022.



3. Future plans

The challenge will be to advance and integrate each element in the future.

R&D Theme

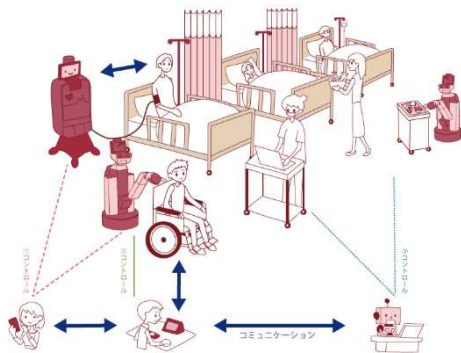
Cooperative control of multiple CAs

Progress until FY2022

1. Outline of the project

This R&D theme is responsible for basic research and development of technology for simultaneous remote control and coordinated control of multiple CAs (flexible CA control). Achievement of this R&D theme will enable a single operator to operate multiple CAs simultaneously, contributing to the realization of an avatar symbiotic society, which is the goal of the project, and to the liberation from space and time constraints, which is the goal of the Moonshot target.

To achieve this, the challenge is to develop technology to use multiple CAs that work while understanding the operator's intentions according to the task and environment. In this R&D



Multi-CA collaboration in a hospital environment

theme, first, the living and hospital room environments in which CAs work together are actually reproduced, and the semi-autonomous CAs that work in these environments are prototyped based on autonomous CA technology that can be

made autonomous from remote operation. Then, a semi-autonomous cooperative control system consisting of multiple CAs will be developed, including BMI and the operation interface.

2. Outcome so far

An integrated system was implemented and a demonstration experiment was conducted.

(1) An integrated system was implemented in which five physically operated CAs could be operated by a single person. A total of five physical CAs can now be operated by a single person in Tokyo x 1 (elderly persons' homes) and Osaka x 2 (elderly persons' facilities and hospitals).

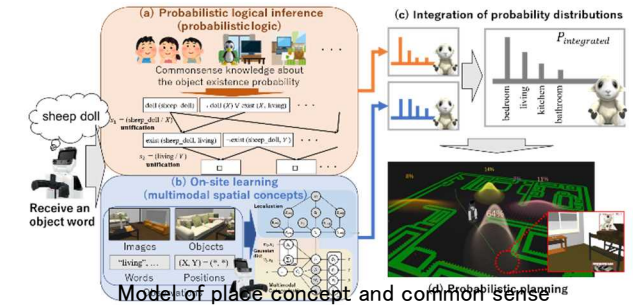


Five physical CAs operation

(2) Experiment of a CA system for taking care of elderly people at elderly people's facilities/hospitals were conducted. We interviewed the staff to find out what kind of CA services were needed, and clarified that it would be good to be able to share information about the activities of the residents with the CA system. An automatic information sharing system using SNS was then implemented.

In addition, the following are representative technologies developed as the basis for flexible CA control.

- (1) Robot world model realization using Transformer
- (2) Development of a cooperative method for multiple CAs
- (3) Implementation of a computational model in CA that



integrates on-the-spot learning based on a place concept model and common sense knowledge based on symbolic logic (4) Developed HLSM-MAT, a method for solving object manipulation instructions, and achieved the world's highest performance in the ALFRED task

(5) Realized smooth and stable grasping using proximity sensors to cope with communication delays.

(6) Achieved BMI voluntary control by decoding intracranial EEG and achieved 95% accuracy in writing operation.

3. Future plans

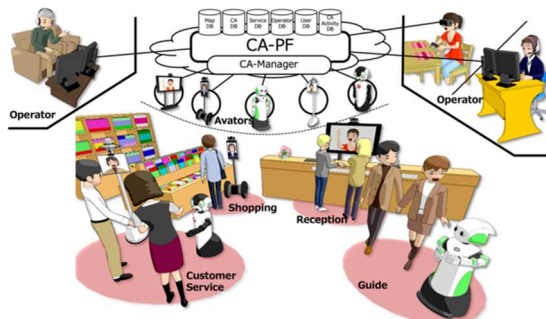
In the future, we will take on the challenge of realizing even more CA simultaneous remote operations. We believe this can be achieved by incorporating the elemental technologies we have developed so far into an integrated demonstration system and building a mechanism for CAs to work together autonomously. In addition, we will promote further development of elemental technologies by continuing field studies.

Development of CA platform

Progress until FY2022

1. Outline of the project

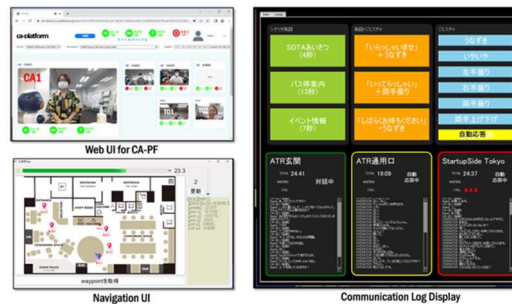
We are developing a software platform for cybernetic avatars (CAs) called the CA platform (CA-PF), which connects multiple CAs and tele-operators, enabling CAs to provide services. To achieve the CA-PF, we first need to clarify the hierarchical structure of the platform, realize the functions of each hierarchy, and define the protocols between the layers. The basic structure comprises a CA monitoring layer, a CA experience management layer, a hierarchical CA control layer, and a tele-operator assignment layer. We are developing a CA-PF prototype based on this basic structure, conducting field experiments to verify its performance, and exploring new research topics for the platform. In collaboration with members of R&D theme 7 (field experiments in the real world) and a corporate consortium associated with the project, we will develop a CA-PF that considers interoperability and scalability of various types of CA services and CA models through field experiments.



2. Outcome so far

- Development of CA-PF and Field Experiments

We examined the practical requirements for utilizing CA and CA-PF in a real-world setting and developed a second prototype of CA-PF, which builds upon the specifications of the initial prototype developed last year. The objective was to improve the connectivity between CA-PF, CAs, and tele-operator PCs, as well as enhance the Web user interface. Through experiments, it was demonstrated that tele-operators were able to control the CAs using the second prototype, even in a mobile environment where they utilized smartphones or notebook PCs with mobile WIFI devices. In the second prototype, we proposed and implemented software modules as “external programs” to enable semi-autonomous control of CAs, along with a switching manager that facilitates the transition between tele-operation and autonomous operation.



These implementations were validated through reception and guidance field experiments at corporate entrances, as well as multi-location reception field experiments conducted at three incubation offices (Tokyo, Kyoto, and Osaka). These experiments were conducted in collaboration with the research groups of R&D theme 1 (Development of CAs with a humanlike presence and lifelikeness) and theme 7 (Field experiments in the real world). They demonstrated the feasibility of providing simulated CA services.

- Standardization of CA Service Function Description

The specifications that describe CA service functions were incorporated into RoSO (Robotic Service Ontology), which is currently undergoing standardization by the Object Management Group's (OMG) Robotics DTF, an international standardization body. The initial draft of RoSO 1.0 was submitted in September 2022. Similarly, the specifications for the CA platform were integrated as an extension of RoIS (Robotic Interaction Service), which is also undergoing standardization within OMG's Robotics DTF. The issuance of the RoIS 2.0 RFP (request for proposal) took place in March 2023.

3. Future plans

The CA-PF is designed to be utilized in various scenarios that involve combinations of CA types, tele-operator environments, CA service provision location situations, and types of CA services. We will progressively develop the CA-PF to support these scenarios and conduct functional verification experiments accordingly. Furthermore, we will expand the sample implementation of the external programs proposed as a framework for integrating the outcomes of other R&D themes.

R&D Theme

Multidisciplinary investigation on how avatars and devices affect users

Progress until FY2022

1. Outline of the project

Our group tries to thoroughly understand how the use of CA and devices affect the human multi-omics network. This group is tightly connected to all other groups in the moonshot goal 1. Deepening our understanding of how CA and devices affect humans will enable us to design CA in light of omics-level biology, evaluate developed CA more objectively, and develop sustainable symbiosis with CA.

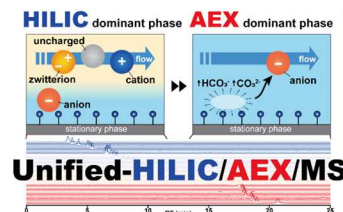
This group utilizes omics analyses where we thoroughly measure > 10,000 different molecules to understand how the use of CA and devices affect e.g., metabolism in humans. This strategy is very different from conventional methods where researchers use text-based psychological surveys and measurements of specific molecules such as cortisol, possibly opening up a completely new venue in this area.

In FY2022, we developed a new metabolomics method that largely advances our omics capacity, investigating how the use of gaming affects human omics networks. We also found that CA has an ability to make people more challenging in certain gambling tasks.

2. Outcome so far

We have developed a new metabolomics method that helps us to achieve our aims. Metabolomics analyses measure various different metabolites from cells. Importantly, each metabolite has unique molecular properties such as molecular weight, polarity, and so on. It is of note that a specific experimental setting in

metabolite measurements is often specialized for specific types of metabolites (e.g., low molecular and hydrophilic), not allowing measurements for



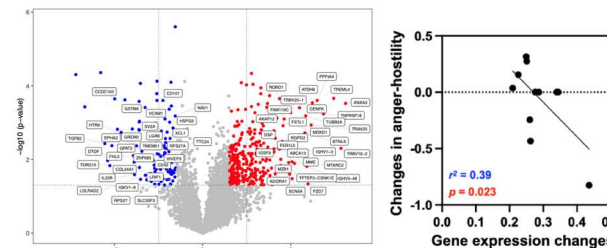
Unified-HILIC/AEX/MS is a newly developed method that enables us to measure various different types of metabolites at the same time and efficiently

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different types of metabolites. Associate Prof. Izumi in our team developed a method called Unified-HILIC/AEX/MS that measures a wider range of metabolites at the same time.

Using our platform, we analyzed human multi-omics during 2h gaming. We found that 2h gaming changes various gene expressions in immune cells. Interestingly, the degrees of gene expression changes were correlated with the reduction in anger-hostility measured by a psychological test POMS2, demonstrating the usefulness of multi-omics analyses to evaluate how CA affects human physiology.

Prof. Haruno in our team addressed the effects of CA in a gambling task using brain response measurements.



In the experiments, participants play a gambling task with an observer, who is either CA or not. Prof.



Haruno revealed that CA alters participants' behavior, making them more challenging in gambling tasks, which was associated with the activity in amygdala. These results clearly demonstrated that CA alters brain activity and human behavior.

3. Future plans

We will reveal how the use of CA and devices affect human physiology under various contexts including gaming, communication, device use, and so on. Our studies will open up new research fields that promote an avatar-symbiotic society in safe and sustainable manner.

Field experiments in the real world

Progress until FY2022

1. Outline of the project

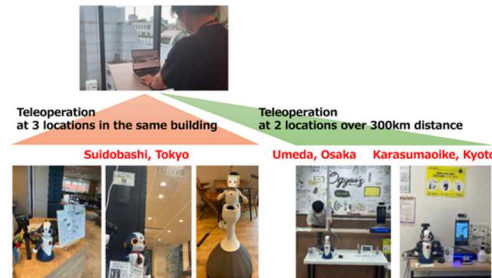
We are developing a field experiment platform that incorporates a specialized communication environment for cybernetic avatars (CAs), allowing us to conduct practical experiments in collaboration with multiple companies. To facilitate this, we will establish a corporate consortium for the project and aim to have approximately 10 companies participate in the field experiments. Through these field experiments and related activities, we will disseminate the results of our R&D project to the world, envisioning the emergence of a new world characterized by an avatar-symbiotic society. Within the scope of this project, we will conduct focused field experiments on mental health care for individuals with mental disorders such as developmental disabilities and depression, as well as social participation for the older adults, in order to explore the realization of CAs and address associated challenges.

2. Outcome so far

- Development of Field Experiment Platform

We have constructed a field experiment platform consisting of three CAs capable of providing reception and guidance services. The platform includes tele-operation software (CA-PF), CAs, and a sensor network for measuring the environment. Regarding communication for CAs, we have extended the core system of 5G communication and implemented 5G resource control technology, which allocates appropriate wireless communication resources based on the predicted locations of mobile CAs. In collaboration with R&D themes 1 and 7, we have developed a mobile CA (Teleco) and a location-fixed CA (Geminoid-TK, a human-like CA with detachable skin). We have

conducted a long-term field experiment for reception and guidance at corporate entrances, multi-location reception experiments where a single tele-operator handles reception at three incubation offices (Tokyo, Kyoto, and Osaka), and a field experiment to investigate the social acceptance of official duties performed by CAs at department stores by utilizing the platform.



- Field Experiments on Mental Health Care for Individuals with Mental Disorders and Social Participation for Older Adults

In the field of mental health care, to appropriately select facial expressions and behaviors that correspond to each individual's mental state, we modeled the settings of them based on a database of interactions, conversations, and physiological data during interactions with individuals with developmental disabilities and patients with depression, which was constructed last year. Furthermore, we conducted field experiments with CAs in medical and educational settings at 12 facilities.



For the experiments targeting the older adults, we developed an interface that allows tele-operation of two CAs and conducted the experiments with the older adults using two tasks. With the cooperation of Sakai City in Osaka, we also established a tele-operation experiment base in Senboku New Town.

- Corporate Consortium

The corporate consortium for Avatar-Symbiotic Society currently has 105 corporations registered as members as of the end of March 2023. Within the consortium, four subcommittees have been formed according to industry and business type, to explore new business opportunities utilizing CA while showcasing the achievements of this project.

3. Future plans

We will continuously improve the field experiment platform and conduct field experiments. In particular, we will focus on back casting type field experiments to disseminate the project concept to general public. Based on the results of these experiments, we will provide feedback on issues and challenges to each R&D theme and incorporate them into the establishment of the CA-PF and international standardization activities carried out under R&D theme 5.

Avatar Social Ethics Design

Progress until FY2022

1. Outline of the project

This research addresses the ethical and legal issues in the use of Cybernetic Avatars (CA) and the realization of moral computing. The social ethics research examines the social, ethical, and even psychological effects that could occur if CA is widely used in the society. The legal research discusses certification systems for avatars, privacy issues, and legal issues in social implementation of avatars. In the engineering approach, we conducted research and development of moral computing. In addition, the Avatar Symbiosis Social Ethics Consortium (Figure 1) is developing guidelines for CA social implementation.

2. Outcome so far

① Avatar Social Implementation Guidelines (Draft)

The members of Symbiotic Social Ethics Consortium have been discussing the issues to be considered in implementing avatars in a society in terms of legal, ethical, and technical perspectives. Based on the discussion, we proposed the Avatar Social

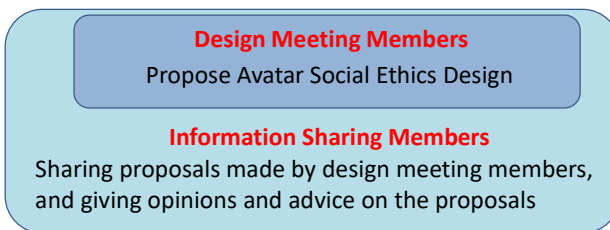


Figure 1: Avatar Symbiotic Social Ethics Consortium

Implementation Guidelines.

◆Aiming to enhance social wellbeing, we need to overcome issues for disseminating new technologies into a society, while considering the issues of concern and trust (legal and ethical issues, etc.) regarding new technologies.

◆[Consideration] Consideration to issues related to concern and trust in CA development.

- Consideration for operators
- Consideration for users

◆[Dissemination] What should be aimed at in disseminating CA to society.

- Give everyone an opportunity to use CA.
- Improve service quality and productivity using CA.
- Contribute to realizing a sustainable society using CA.

②Activities of the Avatar Symbiotic Social Ethics Consortium

We have organized three consortium symposia, three international workshops, four experience-based workshops, and monthly design meetings to discuss the ethical design of avatar society with experts in a wide range of fields (law, ethics, engineering, education, SF writer, etc.).

③In moral computing research, we proposed an operator support system that makes the operator aware of unintentional avatar mis-operation. We also developed a technique that converts operator's inappropriate speech into polite one (Figure 2).

④In social ethics research, we conducted an impression survey of avatar technology and collected opinions of the public for their expectations and concerns about avatars.

⑤We discussed legal issues for 1) identity theft of avatars from

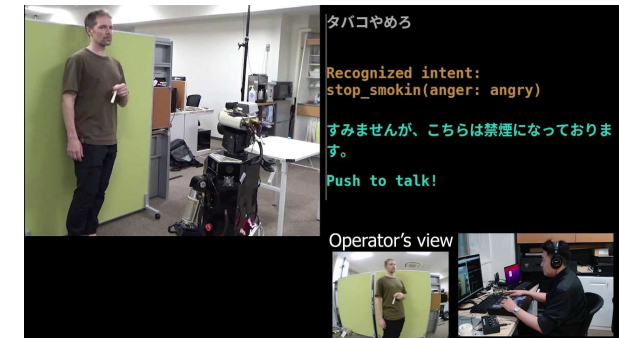


Figure 2: Moral computing system

the perspective of privacy protection, and avatar misuse in a virtual space, 2) institutional issues for avatar certification, and 3) social implementation of avatars that enable interactive discussions by a larger number of people.

3. Future plans

- We will improve and disseminate the Avatar Social Implementation Guidelines by continuing discussions with a wide range of people.

- We will clarify social ethical, legal, and psychological issues through experimental studies.