HATUKI: An anime character like robot figure platform with anime-style expressions and imitation learning based action generation

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Abstract—Japanese character figurines are popular and have pivot position in Otaku culture. Although numerous robots have been developed, few have focused on otaku-culture or on embodying anime character figurine. Therefore, we take the first steps to bridge this gap by developing HATUKI, which is a humanoid robot platform with anime based design. HATUKI’s novelty lies in aesthetic design, 2D facial expressions, and anime-style behaviors that allows it to deliver rich interaction experiences resembling anime-characters. We explain our design implementation process of HATUKI, followed by our evaluations. In order to explore user impressions and opinions towards HATUKI, we conducted a questionnaire in the world’s largest anime-figurine event. The results indicate that participants were generally very satisfied with HATUKI’s design, and proposed various use case scenarios and deployment contexts for HATUKI.The second evaluation focused on imitation learning, as such method can provide better interaction ability in the real world and generate rich, context-adaptive behaviors in different situations. We made HATUKI learn 11 actions, combining voice, facial expressions and motions, through neuron network based policy model with our proposed interface. Results show our approach was successfully able to generate the actions through self-organized contexts, which shows the potential for generalizing our approach in further actions under different contexts. Lastly, we present our future research direction for HATUKI, and provide our conclusion.

I. INTRODUCTION

The Japanese term Otaku refers to a person who is a fan of a specific subculture, yet such term has become synonymous with people who are fans of Japanese anime (animated cartoons), manga (comics), and video games [1], [2]. Overall, the Otaku culture has become a worldwide phenomenon, fostering many local communities, societies and global events revolving around related hobbies [2],[3].

An essential aspect of the Otaku culture is figurines, which present a physical embodiment of virtual characters from Japanese anime, manga or video games. These figurines resemble 2D-like facial features that are commonly found in Japanese anime and manga designs. The rising global popularity of the Otaku cultures and advancements in mass-production made figurines highly desired items by fans of the Otaku culture worldwide.

Despite the massive popularity of Otaku culture worldwide, we believe robotics had a minimum contribution to such a culture. There is a scarcity of research literature that investigated potential applications of robotics within the Otaku culture. Especially, we believe that potential applications can span beyond previously investigated applications of entertainment robots, where they can directly contribute to business profitability and value creation [4], similar to figurines.

In this work, we introduce HATUKI, which is a humanoid robot that is uniquely designed to resemble 2D anime designs found in Fig. 1. HATUKI bridges the gap between figurines and humanoid robots through its unique design and functional capabilities. As a platform, HATUKI and its design process can be used to embody various anime-like characters in terms of aesthetics, expressions, and behavior.

Accordingly, we start by explaining the design and implementation specifications of HATUKI, followed by two evaluations. Similar to previous approaches [5], [6], [7], we focused our first evaluation on investigating users’ impressions of HATUKI through a survey, which was handed out to visitors of HATUKI’s exhibition booth at the largest figurine exhibition in the world (Wonder Festival [8]). Results show that participants regarded HATUKI as a combination of a figurine and a humanoid robot, proposed various intriguing
use cases of Hatsuki within public and private usage contexts [9], and were generally very satisfied with Hatsuki.

Interaction in the real world is hard to predict, and creating pre-defined robot actions for every world situation is impossible. Imitation learning is one approach to enable context-adaptive interactions for different situations, it is especially useful in enabling the system to perform actions through learned policy with contextual inputs (e.g. sensory information, motor information or any internal states) and to perform various behaviors. Moreover, this approach does not require pre-defining every action-state situation, but directly learns from operators’ experience to generate a policy in order to perform human-like behavior.

Our second evaluation focuses on performing imitation learning for eleven expressive actions of Hatsuki, which were acquired through kinesthetic teaching. The results indicate that the trained neuron networks based policy successfully generates the actions and self-organize the context neurons for each different trajectory.

Lastly, we conclude that Hatsuki’s evaluation results were very encouraging to pursue future works. We highlight a number of future research directions that allow Hatsuki to be applicable within a variety of novel interactive contexts of use.

We summarize the main contributions of our work as follows: 1) Design and implementation of Hatsuki, which embodies anime-character designs into an interactive humanoid robot. 2) Evaluation results that explored overall impressions of Hatsuki, and applicability of imitation learning for use in different interactive contexts.

II. RELATED WORKS

Our work extends three strands of related works on Humanoid Robots, Animatronics, and Entertainment Robots. We discuss each of these domains as follows:

Humanoid robots such as Twendy-one [10], Asimo [11] are designed for in-door daily life support. A subcategory of these robots attempts to resemble realistic human-designs. For example, Gemiroid [12] and Sophia [13] presented very realistic human-like appearance. Such an approach requires comprehensive design, makeup skills and integration efforts to design every aesthetic detail. Hatsuki takes a different approach as it is based on anime-character figurines. In addition, unlike mentioned works that emphasize daily life services, Hatsuki is designed to emphasize entertainment applications related to the Otaku culture.

The design direction of Hatsuki is similar to “Animatronics”, which are electro-mechanically animated robots that aim to mimic life-looking characters or creatures [14]. Various previous efforts presented vivid robots, such as humans [14] or animals [15] for the entertainment industry. Similarly, Hatsuki shares similarities with the works in animatronics, yet extend such works through novel aesthetic design and behaviors that mimic Japanese anime characters beyond existing works.

Entertainment Robots is a subcategory of robots that are mainly concerned with applications like singing, dancing and various performances [16]. For example, Kousaka Kokona is an adult-size humanoid robot designed for entertainment, like singing and dancing [17]. Similarly, other robots [18] provide similar functionalities in smaller body proportions. Although some of the mentioned robots (e.g. [17], [18]) are designed with doll-like aesthetics, these robots are limited; they lack anime-like facial expressions, speech or autonomous interactivity. On the contrary, Hatsuki advances the state of the art by its superior design and interactive modalities, like speech, facial expressions and body gestures. Therefore, Hatsuki presents a thorough embodiment of anime-character designs beyond previous works, thereby providing various novel interaction potentials. The novelty of Hatsuki can translate to profitability and create value to consumers, in a similar fashion to previous efforts within entertainment robots [4].

III. DESIGN AND IMPLEMENTATION OF HATSUKI

The design approach of Hatsuki uses the outside-in [19] design approach; which refers to an aesthetics-orient design process. For usual engineering product designs, inside-out approach is considered easier to apply due to its functional-oriented design, which starts by designing functional components of the system, followed by designing aesthetic aspects. On the contrary, the outside-in process starts with emphasizing the aesthetic design of the robot, then proceeds to implement the technical/mechanical design of the robot in an iterative fashion. Overall, our outside-in design process is iterative and combines CAD and engineering design as well as common high-polygon 3D modeling designs. Accordingly, we adopt an outside-in design process to design and implement the various components of Hatsuki. First, we discuss the appearance of Hatsuki, followed by the facial expression system. Next, we introduce our implementation of mechanical and structural components, control and action generation in Hatsuki.

A. Appearance

Fig. 2. Hatsuki extends popular anime culture character designs by embodying a Mecha-Musume character model. Such design direction combines mechanical and anthropomorphic attributes into the aesthetics of the character.
A Japanese anime character usually applies simplified 2D characteristics, which people use to distinguish a character and largely favored in Otaku culture [20]. These characteristics are hairstyle, hair color, eye shape, pupils style, pupils color and eye’s high-light style, especially for the main protagonist of the story who usually be designed delicately [21]. Characters who do not rely on mentioned characteristics are usually recognized through unique clothes or decorations design to improve distinguishability (e.g. special hairpin on specific position). We considered mentioned aspects to design Hatsuki and make her unique and distinguishable.

The art style of design applies “Mecha-Musume”, which is a popular category in Otaku culture. This art style refers to a character that is female-like with mechanized design decoration or body parts. This art style blend mechanized design with a humanoid character, which can enable people to recognize Hatsuki as a non-human character. The final character design compared to the actual finished prototype is shown as Fig.2 and the appearance and dimension of Hatsuki is shown as Fig.3.

**Fig. 3.** Hatsuki has short brown hair, purple eyes, 145 centimeter tall, 1:5.5 body proportions [22] (head-to-body ratio), which resembles a common anime-character design attributes [23].

**B. Facial Expression**

Common anime character’s facial expressions hugely vary, from human-like to abstract expressions and patterns, and such facial expressions represent a character’s mind status directly [21]. This characteristic is important for enriching the character’s personality. Therefore, we designed a wide variety of facial expression which are common in anime characters. A rear projection is integrated to Hatsuki to project the expressions in 2D onto Hatsuki’s face as in Fig.4.

We apply projection mapping to project facial expression to a 3D organic face screen. Unlike [25] trying to apply real human textures, Hatsuki’s facial expression is essentially 2D animation which does not suffer from mesh un-matching issue that much.

The calibration of projection mapping is shown as Fig.5 which applied with a parameter controllable facial texture model to perform vivid facial expressions.

**Fig. 4.** Hatsuki use a rear projection facial expression system to provide rich anime-like facial expressions. Unlike physical facial expression mechanism (e.g. [24]), our system is able to express a further variety of facial expressions without limitation.

**Fig. 5.** Calibration of facial expression on 3D organic face: (1) First, we trace drawing 2D facial illustrate and animation with front view of the face 3D model. (2) After creating facial material, we do texture projection on the 3D mesh. (3) Recapture the projected texture from the projector lens position and output image to the projector.

**C. Mechanical Structure and Sensing**

Hatsuki’s body is constructed using 3D printed PLA parts (Polylactic Acid). We chose PLA as it is lightweight yet robust enough to withstand the weight of various body parts. Our current implementation focuses on the upper torso design and motions. Therefore, Hatsuki currently (Mk.I version) has 17 DoFs in total, where we used a variety of servo motors to actuate different sections of Hatsuki (Table 1). We explain each of these sections as follows:

**Head and Arms:** We used three servomotors (XM430) to actuate the head as well as each arm. The shoulder joint consists of servo XM540, which provides higher torque that can be used for lifting or holding objects.

**Fingers:** To actuate the fingers, we use Futaba S3114 RC servo motors connected directly to the Arduino Nano’s PWM pins (Pulse Width Modulation). We implemented a tendon-driven mechanism to achieve a human-size hand. Each tendon is attached to a servo motor head, where its position can be controlled by changing the PWM signal of Arduino Nano directly from a PC via serial communication.

**Ears:** We use two HobbyKing HK15148 analog servo motors (also connected to an Arduino Nano) to actuate the ears.
VR device. Facial expression and audio can be added to connected to the PC using USB. Microcontrollers to control all other servomotors, which are directly control the servomotors. We used two Arduino nano RS-485 to a USB converter (U2D2), which allows us to the Hatsuki’s confined design. Drastically enabled good overall cable management within the Robotis servo motors communicate via RS-485 (4-wires) and can be daisy-chained through serial communication. This setup servo motors communicate via RS-485 (4-wires) and can be used in imitation learning studies. Lastly, the Robotis servo motors are powered using a 12 V power supply, while the Futaba servo motors and HobbyKings servo motors are powered from a 6 V power supply.

Sensors: Hatsuki’s head embeds an Intel RealSense D435 RGBD camera and a generic Bluetooth speaker. The Robotis servomotor also provides feedback, including position and output current sensor that enables estimating applied torque on the motors.

D. Control Infrastructure

The main controller of Hatsuki is a gaming PC, which allows us VR control or for machine learning. The control interface uses the game engine "Unity3D" due to its flexibility to develop interactive applications. Robotis SDK and serial communication are used to control the Robotis and Arduino nano, respectively. Our control architecture is modular, and was implemented using multiple Unity scenes as shown in Fig.6. Each scene is created to control a specific aspect of the robot, including various control parameters and attributes. New robot functionalities or sensors can easily be created or integrated by creating new scenes. Therefore, we chose a modular implementation of our system as it provides benefits in terms of development and maintainability of interactive applications.

E. Action Recording

The action refers to the performance of the robot such as motion, facial expressions, audio performance, etc. which can be observed. For motion, Hatsuki provides two style of motion recording, Kinesthetic Teaching and record through VR device. Facial expression and audio can be added to the recorded trajectory and create a synced command with motion.

1) Kinesthetic Teaching: Kinesthetic Teaching is a common method for teaching motor skills of the robot. An operator moves the robot’s body to perform motions by cutting down the torque supply for actuators and keep retrieving encoders data continuously. For most of the industrial robots, it may be hard to do kinesthetic teaching due to robot inertia, however, since Hatsuki is mostly built with 3D print material, it relatively light-weight and can be easily moved.

2) Record through VR device: Hatsuki also provides Virtual Reality(VR) device HTC Vive control interface to capture the movements of an operator and transfer them to the robot. The VR trackers are used to control Hatsuki’s hands, where the mapping between the VR trackers and each joint angle is first calculated through Inverse Kinematics (IK) within Unity3D, and then applied to the robot servomotors. The IK algorithm utilizes an evolutionary algorithm based method "BioIK"[28] which can create full-body, multi-objective and highly-continuous motions.

F. Implementation of Imitation Learning

The policy refers to a set of rules (or state) that describe how AI chooses its action to take. In this case, it represents the output model or a function that can output the action with the state input. Imitation learning is possible to learn the policy from performing tasks to the dynamic motion generation. Such works show the advantage of learning from human operator experience capable of performing human-like behaviors while also good at interacting with an object or the environment. By applying our neural networks based policy model, it can generate context-dependent actions that provide more variety of actions. The context can be sensory-motor information or any designed or generated contexts.

The implementation of imitation learning is shown in Fig.7 and we proceed with trained policy model embedded with the integrated scene in our control infrastructure. For training

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**TABLE I SERVO MOTORS SPECIFICATIONS**

| Specifications | XM430 | XM540 | S3114 | HK15148 |
|----------------|-------|-------|-------|---------|
| Weight (g)     | 82    | 165   | 7.8   | 15      |
| Stall Torque   | 4.1(12V) | 10.6(12V) | 0.17(6V) | 0.2(6V) |
| Speed (RPM)    | 46(12V) | 30(12V) | 100(6V)  | 55(6V)  |
| Voltage (V)    | 10.0 - 14.8 | 10.0 - 14.8 | 4.8 - 6.0 | 4.8 - 6.0 |
policy, we used a multiple time-scale recurrent neural network (MTRNN) [31] due to its powerful performance [32] to learn the relationship between facial-sound expression and motor information. The MTRNN is composed of three types of neurons: input-output (IO), fast context (Cf), and slow context (Cs) neurons. The model effectively memorizes the trained sequences as combinations of the dynamics of Cf and Cs neurons.

Fig. 7. The outline of training imitation policy

IV. EVALUATION 1: INVESTIGATING IMPRESSIONS AND OPINIONS TOWARD HATSUKI

Hatsuki’s unique design and applications have various intriguing multidisciplinary challenges. First, we focus on investigating user’s impressions and exception of Hatsuki. Second, we evaluate the use of imitation learning for producing different expressions.

A. Study Design and Procedure

Objective: To investigate the challenges and opportunities of novel robotic platforms from the user’s perceptive, various previous works have utilized user-centered design approaches [5], [7], [33], [6] to gain insights about user impressions and expectations of such platforms. Accordingly, our main evaluation objective is to investigate the impressions and opinions about Hatsuki’s design and to gain insights about highly-desired applications. We focused on how Hatsuki’s aesthetics, behavior, and tasks are perceived by anime fans when compared to common anime characters and figurines.

Method: We extended the questionnaires in previous works [5], [7], [6], [34] to design a survey that measured users’ satisfaction of Hatsuki’s design, as well as interaction expectations during public and private usage contexts. As Hatsuki is mainly designed to target anime and figurine fans, we carried out our survey at Wonder Festival 2020 [8], which is the biggest anime figurine event in the world. We exhibited various interactive experiences of Hatsuki (Fig.8), such as greeting visitors, talking to them and posing for selfies. All experiences utilized various capabilities of Hatsuki, such as speech, facial expressions, hand gestures.

Visitors first were given a chance to interact with Hatsuki and discuss its various capabilities with four researchers. Next, visitors were handed the survey (as described below), and researchers followed-up with visitors to ensure they understood and answered the questions correctly. Each visitor took around 10-15 minutes to complete the survey and was handed a Hatsuki seal as a reward.

Survey: the survey included 16 questions, that were separated into four sections. The first section includes demographic questions. To ensure the participants are within our targeted audience, the second section included questions that gauged how much each participant is into anime and figurine cultures; we asked questions about numbers of collected anime figurines and the time spent on each of mentioned hobbies. In general, participants who are fond of such culture would have many figurines and would dedicate time on a daily basis for related activities.

Figurine culture has an associated collectability value [35]; it is very common for people to collect and exhibit figurines of their favorite anime characters. Therefore, we wanted to know whether or not Hatsuki is perceived as a figurine, and thereby has collectability value.

The third section focused on understanding basic impressions of Hatsuki. Accordingly, we included brainstorming questions about the visitors’ most desired use cases, whether they perceived Hatsuki as a figurine or a robot, and their overall satisfaction with Hatsuki. The fourth section included a detailed rating of Hatsuki’s various body locations. We have chosen to focus on the mentioned aspects as they provide insights about our design direction of Hatsuki and it is perceived from the viewpoint of our target audience.

Participants: We asked 51 visitors to our booth to take our survey. Participants were aged between 20-51 (m=41.6, females=2). Most participants were Japanese (33), while the remaining 18 came from various Asian and European countries. Participants reported spending 4.7 hours (SD=5.02) on Otaku culture activities (anime or figurines), and reported owning an average of 31 anime figures (SD=36.32), with 30 participants owning 10 to 100 figures. Therefore, in addition to being visitors to the largest anime figurine conventions, we conclude that the participants fell into our target audience.

B. Results and Analysis

The gathered results indicate a variety of intriguing aspects regarding participants’ expectations and impressions toward Hatsuki. Accordingly, we classified results based on the before mentioned survey sections and discuss them in the following subsections.

1) Impressions of Hatsuki’s Design: We asked participants to rate Hatsuki’s aesthetic design (Fig.9). Overall, the results indicate that participants liked Hatsuki’s design
under three categories. First, the majority of tasks fell under companionship. Applications (participants proposed a total of 59 use cases). Daily life assistance (15 use cases in different contexts (e.g. during dinner or before going to bed)), and providing companionship (e.g. playing music and scheduling, similar to smart home devices).

We asked participants about the most suitable interaction context for Hatsuki. 65.22% of the participants thought that Hatsuki is better suited for public contexts, citing examples of anime events, conferences and tourist attractions as potential deployment venues. Moreover, participants provided many references from pop-culture and anime characters to give examples of proposed tasks in public context, like virtual entertainment performers (e.g. Hatsune Miku [36]).

3) Discussion: The results indicate that our design direction is highly favored, and participants provided various insights to further enhance our design direction. Likewise, the proposed use cases provided insights about potential application and deployment contexts. Participants rated their overall satisfaction with Hatsuki with 5.65 (SD=1.48, 7 is best). Therefore, we believe Hatsuki was generally well-received. A correlation analysis (Pearson product-moment correlation) to understand which aspect of Hatsuki’s aesthetic ratings affected satisfaction revealed significant results for the face (r=0.687, n=50, p<0.001). Additional tests turned negative for other body parts. Therefore, we conclude that Hatsuki’s face was most significant in affecting the overall satisfaction score, which indicates the importance of designing robust facial features and expressions for this form of robots.

Although some proposed applications of Hatsuki have been investigated before (e.g. [24], [4]), we believe Hatsuki advances the state of the art through its unique design; Hatsuki can be designed to embody any virtual character, from anime or pop-culture, thereby enabling experiences beyond what has been mainly investigated in social robots. For example, the familiarity of users with anime figurines characters can be used as a pretext to initiate and carry out various tasks. Such a pretext can be a significant factor in establishing familiar and trust-worthy interactive experiences.

Another interesting result is whether or not participants would consider Hatsuki a figurine with robotic components. We asked visitors to rate whether they consider Hatsuki a robot, similar to common service or companion robots, or a figurine (7 means Hatsuki is a figurine). The average response was 4.05 (SD=1.59), where most participants indicated that Hatsuki is both a figurine and a robot; since Hatsuki is designed to resemble common figurines, yet could move and interact with visitors. We believe this result verifies our design direction in Hatsuki, as it confirms that Hatsuki’s design provides an appeal to visitors to pose, interact and potentially buy Hatsuki in similar to common anime figurines.

There is lack of female participants in our questionnaire, which is due to the event being mainly targeting male visitors [8]. Therefore, we intend to carry out a survey.

![Fig. 9. Participants’ rate of Hatsuki’s aesthetic design with emphasis on specific body sections (1-7 likert-scale, 7 is best).](image)
with other demographics, such as with predominantly female participants or in other countries. We believe such research direction would yield deeper insights about Hatsuki’s appeal in varied target groups.

Overall, the results indicate that Otaku culture fans highly appreciated Hatsuki, and provided a variety of desired tasks within public and private contexts. Therefore, we are encouraged to further use Hatsuki as a platform for research by realizing proposed tasks and deploying Hatsuki within incoming Otaku events.

V. EVALUATION 2: IMITATION LEARNING

We evaluated our method from the viewpoint of the imitation learning platform with a MTRNN policy. By using imitation learning, the proposed method enables the robot to generalize actions without designing many action details. This is useful for making the character more lifelike with natural motions based on observed context, rather than pre-recorded ones. In this study, we performed imitation learning with time-series data obtained by using the Hatsuki platform.

A. Experimental Setup

For training data, we obtained ten motion patterns by the kinesthetic teaching, as described in the section III.E. The ten actions are the following: 1) self-introduction, 2) feeling challenged, 3) angry, 4) annoyed, 5) confused, 6) rejection, 7) hating something, 8) joy, 9) sad, 10) & 11) two expressions of agreeing with the user. Each motion pattern consists of 17-dimensional joint angles, facial expression commands, and audio commands. We converted facial expression and audio commands to a one-hot vector format, and incorporated them into time-series data. The value input to the MTRNN was scaled to [-1.0, 1.0]. We set parameters of our model according to the previous study [32].

B. Results

Using Hatsuki, our approach successfully generated the sequence of actions, which includes motions, facial expressions and voice expressions. The generated actions are shown as Fig.10 and all actions can be found in the supplementary video. The motion is generated by inputting the initial value of Cs and the initial posture of the robot to MTRNN. The errors in the generated trajectories are small, indicating that the model has successfully learned high-dimensional motions. We also visualized the internal state of the MTRNN by principal component analysis (Fig.11). Each color in Fig.11 indicates the trained sequences. We also confirmed that each motion pattern was separated and that the MTRNN can generate robot behaviors from the initial value of Cs successfully.

We discussed the effectiveness of the proposed method from the viewpoint of the reduction in the number of work steps of imitation learning. In the conventional imitation learning methods, the process of linking the robot controller with the projection mapping, facial expression, and audio perform requires the following four processes: (1) Acquisition of robot motion by using the kinesthetic teaching, (2) Synchronization of motion data, facial expression, and audio perform, (3) Training the model of the MTRNN policy, and (4) Loading the trained model into the system, and synchronizing the robot motion, acquisition of sensor information, and expression of robot.

Overall, the above processes utilizes our multi-scene structure that was developed in Unity3D (Fig.6), which provides high flexibility to integrate various robot control modules. Therefore, we believe the modularity of our system reduces the system switching-cost upon deploying different control modules that is associated with conventional robotic system.

VI. CONCLUSION AND FUTURE WORK

In this paper, we presented Hatsuki, which is a humanoid robot that is designed to resemble anime figurines in terms of aesthetics, expressions and movements. We explained our implementation specifications and potential applications. We carried out an evaluation to understand user impressions regarding Hatsuki’s design, as well as potential usage scenarios. We also carried out an evaluation using imitation learning which shows it can successfully perform action generation through learnt policy model effectively.

Overall, the results are very encouraging to pursue further work. We believe Hatsuki was generally liked by visitors, and they thought Hatsuki is an embodiment of anime-characters in real life. Therefore, we will focus on investigating applications and available hardware design of Hatsuki within the Otaku culture worldwide. In the future, we intend to improve our design by implementing better robot hand for object manipulation and human interaction, as well as bipedal system so Hatsuki can walk and demonstrate full body movements.

Lastly, we believe that features like branching stories [37] and dating simulators [38] are highly sought after features of anime style games. Such features provide interactive and unpredictable elements, which were also found to be greatly
liked features of entertainment robots [39]. Therefore, we intend to realize similar features in Hatsuki. Our evaluation results show the potential of imitation learning to provide adaptive behaviour to different interactive contexts, such as motions, facial expressions or speech, which can be used to provide traits similar to anime-style games. Therefore, we intend advance our work in this direction and using Hatsuki as a deployment platform.

REFERENCES

[1] A. Newitz, “Anime otaku: Japanese animation fans outside Japan,” 1994.

[2] M. Hills and E. G. McGregor, “Transcultural otak: Japanese representations of random and representations of Japan in anime/manga fan cultures,” 2002.

[3] A. S. Lu, “The many faces of internationalization in japanese anime,” Animation, vol. 3, no. 2, pp. 169–187, 2008.

[4] R. Matsumura, M. Shiomi, and N. Hagita, “Do an animation character robot increase sales?” in Proceedings of the 5th International Conference on Human Agent Interaction, ser. HA’17. New York, NY, USA: Association for Computing Machinery, 2017, pp. 479–482.

[5] V. Vatsal and G. Hoffman, “Wearing your arm on your sleeve: Studying usage contexts for a wearable robotic forearm,” in 2017 26th IEEE International Symposium on Robot and Human Interactive Communication (RO-MAN), Aug 2017, pp. 974–980.

[6] H. Jiang, S. Lin, V. Prabakaran, M. R. Elara, and L. Sun, “A survey of users’ expectations towards on-body companion robots,” in Proceedings of the 2019 on Designing Interactive Systems Conference, ser. DIS ’19. New York, NY, USA: Association for Computing Machinery, 2019, pp. 621–632.

[7] M. Al-Sada, T. H¨oglund, M. Khamis, J. Urbani, and T. Nakajima, “Orochi: Investigating requirements and expectations for multipurpose daily used supernumerary robotic limbs,” in Proceedings of the 10th Augmented Human International Conference 2019, ser. AH2019. New York, NY, USA: Association for Computing Machinery, 2019.

[8] “ワン デーベスト ディバベルとは[about wonder festival],” [Online]. Available: https://wnotes.jp/knowledge/about/wonderfestival/Accessed: 10[March]2020.

[9] A. K. Pandey and R. Gelin, “A mass-produced sociable humanoid robot: pepper, the first machine of its kind,” IEEE Robotics & Automation Magazine, vol. 25, no. 3, pp. 40–48, 2018.

[10] Sugano Lab., “TWENDY-ONE.” [Online]. Available: https://twendyon.de/(Accessed: 9[March]2020)

[11] Honda Motor Co., Ltd., “ASIMO.” [Online]. Available: https://www.honda.co.jp/SIMO/ASIMO/Accessed: 9[March]2020.

[12] Hiroshi Ishiguro Laboratories, ATR, “Understanding and transmitting human presence.” [Online]. Available: http://www.geminoid.en/jpn/projects.html/(Accessed: 29[February]2020).

[13] J. Retto, “Sophia, first citizen robot of the world,” ResearchGate https://www.researchgate.net, pp. 2–9, 2017.

[14] G. M. Poor and R. J. K. Jacob, “Introducing animatronics to hci: Extending reality-based interaction,” in Human-Computer Interaction: Interaction Techniques and Environments, J. A. Jacko, Ed. Berlin, Heidelberg: Springer Berlin Heidelberg, 2011, pp. 593–602.

[15] Y. Terada and I. Yamamoto, “An animatronic system including lifelike robotic fish,” Proceedings of the IEEE, vol. 92, no. 11, pp. 1814–1820, Nov 2004.

[16] Y. Kuroki, M. Fujita, T. Ishida, K. Nagasaka, and J. Yamaguchi, “A small biped entertainment robot exploring attractive applications,” in 2003 IEEE International Conference on Robotics and Automation (Cat. No.03CH37442), vol. 1, Sep. 2003, pp. 471–476 vol.1.

[17] Speecys, “Product.” [Online]. Available: http://robo-pro.com/speecys/products/index.html/(Accessed: 29[February]2020)

[18] Asratec Corp., “Se-01.” [Online]. Available: https://www.asratec.co.jp/portfolio-page/se-01/(Accessed: 10[March]2020).

[19] K. M. Kim and K. P. Lee, “Two types of design approaches regarding industrial design and engineering design in product design,” 11th International Design Conference, DESIGN 2010, pp. 1795–1806, 2010.

[20] T. Miyahara, D. Kim, and T. Ishii, “An evaluation study of preferences between combinations of 2d look shading and limited animation in 3d computer animation,” International Journal of Asia Digital Art and Design Association, vol. 19, no. 3, pp. 73–82, 2015.

[21] CC動漫社, “漫畫中的經典表情[classic facial expressions in mangas],” in 漫畫技法講座[基礎編]Manga Skill Bible 1 Basic, 1st ed. Taipei: 格來股份有限公司, 2012, ch. 4.2, pp. 86–92.

[22] CC動漫社, “了解頭身比[understanding body proportions],” in 漫畫技法講座[基礎編]Manga Skill Bible 1 Basic, 1st ed. Taipei: 格來股份有限公司, 2012, ch. 5.1, pp. 94–102.

[23] P. W. Galbraith, “Moe: Exploring Virtual Potential in Post-Millennial Japan,” electronic journal of contemporary japanese studies, no. 5, 2009.

[24] J. Nakanishi, I. Kuramoto, J. Baba, K. Ogawa, Y. Yoshikawa, and H. Ishiguro, “Continuous hospitality with social robots at a hotel,” SN Applied Sciences, vol. 2, no. 6, pp. 1–10, 2020.

[25] T. Kuratate, B. Pierce, and G. Cheng, “’Mask-bot’ – a life-size talking head animated robot for AV speech and human-robot communication research,” Avsp, 2011.

[26] H. Ito, K. Yamamoto, and T. Ogata, “Development of Integration Method of Element Motions using Deep Learning,” The Proceedings of JSME annual Conference on Robotics and Mechatronics (Robomes), vol. 2018, no. 0, pp. 1A1–D09, 2018.

[27] B. Akgun, C. Makmak, J. W. Yoo, and A. L. Thomaz, “Trajectories and keyframes for kinesthetic teaching: A human-robot interaction perspective,” HRI’12 - Proceedings of the 7th Annual ACM/IEEE International Conference on Human-Robot Interaction, pp. 391–398, 2012.

[28] S. Starke, N. Hendrich, D. Krupke, and J. Zhang, “Evolutionary multi-objective inverse kinematics on highly articulated and humanoid robots,” IEEE International Conference on Intelligent Robots and Systems, vol. 2017-Sept, no. September, pp. 6495–6496, 2017.

[29] P.-C. Yang, K. Sasaki, K. Suzuki, S. Sugano, and T. Ogata, “Repeatable folding task by humanoid robot worker using deep learning,” IEEE Robotics and Automation Letters, vol. 2, no. 2, pp. 397–403, April 2017.

[30] X. B. Peng, P. Abbeel, S. Levine, and M. van de Panne, “Deepmimic: Example-guided deep reinforcement learning of physics-based character skills,” ACM Trans. Graph., vol. 37, no. 4, pp. 143:1–143:14, July 2018.

[31] Y. Yamashita and J. Tani, “Emergence of functional hierarchy in a multiple timescale neural network model: A humanoid robot experiment,” PLoS Computational Biology, vol. 4, no. 11, pp. e00220–1–e00220–18, 2008.

[32] K. Suzuki, H. Mori, and T. Ogata, “Motion switching with sensory and instruction signals by designing dynamical systems using deep neural network,” IEEE Robotics and Automation Letters, vol. 3, no. 4, pp. 3481–3488, Oct 2018.

[33] M. A. Sada, M. Khamis, A. Kato, S. Sugano, T. Nakajima, and F. Alt, “Challenges and opportunities of supernumerary robotic limbs,” 2017.

[34] J. P. Chin, V. A. Diehl, and K. L. Norman, “Development of an instrument measuring user satisfaction of the human–computer interface,” in Proceedings of the SIGCHI conference on Human factors in computing systems, 1998, pp. 213–218.

[35] H. Masuda, T. Sudo, K. Rikukawa, Y. Mori, N. Ito, Y. Kameyama, and M. Onouchi, “アニメ産業レポ[anime industrial report 2019],” The Association of Japanese Animation, Tech. Rep., 2019. [Online]. Available: https://www.spi-information.com/report/24755.html.

[36] F. Greenwood, “The girl at the center of the world: Gender, genre, and remediation in bishojo media works,” Mechademia, vol. 9, pp. 237–252, 2014.

[37] 5pb.jp, “Ps vita : yahari game demo ore no seishun zoku [understanding body proportions],” in ハロウィンアートフェスティバル２０１９[anime industrial report 2019].” [Online]. Available: http://5pb.jp/games/oregairu/story/(Accessed: 5[October]2020).

[38] Konami Digital Entertainment Co., Ltd., “ラブプラス 俺の体を好きってね [loveplus every official site].” [Online]. Available: https://www.konami.com/games/loveplus/every/(Accessed: 10[March]2020).

[39] H. Ohi, S. S. Kwak, and M. Kim, “Application of unexpectiness to the behavioral design of an entertainment robot,” in 2010 5th ACM/IEEE International Conference on Human-Robot Interaction (HRI), March 2010, pp. 119–120.