Cyborgs, Human Augmentation, Cybernetics, and JIZAI Body

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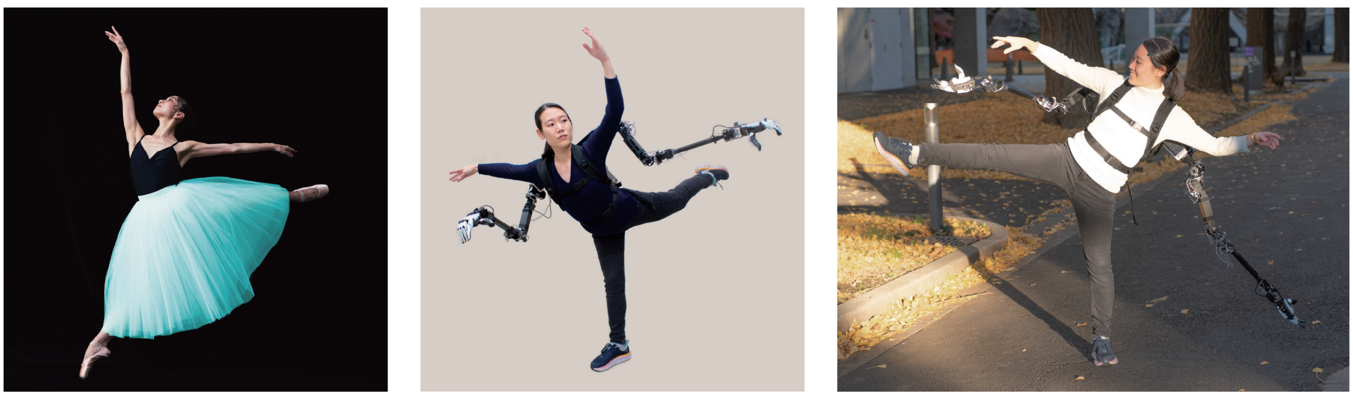

Figure 1: Visionary images of the JIZAI Body. Left: A ballerina beautifully moves her body, Center and Right: An augmented ballerina moves her body and wearable robotic arms as she wishes in every situation.

ABSTRACT

We propose a concept called "JIZAI Body" that allows each person to live the way they wish to live in society. One who acquires a JIZAI Body can (simultaneously) control (or delegate control) of their natural body and extensions of it, both in physical and cyberspace. We begin by describing the JIZAI Body and the associated JIZAI state in more detail. We then provide a review of the literature, focusing on human augmentation and cybernetics, robotics and virtual reality, neuro and cognitive sciences, and the humanities; fields which are necessary for the conception, design, and understanding of the JIZAI Body. We then illustrate the five key aspects of a JIZAI Body through existing works. Finally, we present a series of example scenarios to suggest what a JIZAI society may look like. Overall, we present the JIZAI Body as a preferred state to aspire towards when developing and designing augmented humans.

CCS CONCEPTS

• **Human-centered computing → Human computer interaction (HCI)**; • **Computer systems organization → Embedded and cyber-physical systems**;

KEYWORDS

Cyborg, Human Augmentation, Extended Body, Cybernetics, JIZAI, Robotics, Virtual Reality, Virtual Body, Cognition, Embodiment, Neuroscience, Phenomenology

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1 INTRODUCTION

1.1 The Human Body in the Cyber-Physical Society Since the 4th Social Structural Revolution

Human beings, also known as "Homo Faber," have used the power of tool-making (i.e., technology) to bring about three social structural revolutions to expand their scope of life, developing from hunting, to agriculture, to industry, and, most recently, to information. Interpreting the discourse on tools and human evolution by UC Berkeley anthropologist Sherwood Washburn as a suggestion that "Tools Invented Man," the British writer Arthur C. Clarke argued that the social structural revolution has been accompanied by the evolution of the human body [10]. Namely, that each social structural revolution involved a transformation of the human body.

A side effect of this relation is that those who could engage in the new key industries created by each revolution were seen as being the "Standard Human," while those who could not were classified as disabled in some way. Just as the agricultural and industrial revolutions resulted in individuals being labeled a "Standard Human" or "disabled," we are now seeing a similar effect in the emergence of the "Digital Divide" during the information revolution. In response to each social structural revolution, conventional research, technological development, and policymaking have been conducted with the goal of "enabling the disabled" by bringing them closer to the "Standard Human."

While the creation of an information society has resulted in the digital divide, it has also brought forth diversification of employment and behavior. The image of a "Standard Human" has faded away, and "non-standard" people have found ways to be active in society. Even people with physical disabilities are capable of generating income with a single computer. Some drivers working for ride-sharing businesses like Uber and Lift use machine translation to compensate for their hearing disabilities [1]. The need to conform to the "standard" is fading, and individuality and difference are now seen as a source of new value and innovation. This trend suggests the need for new assistive technologies that go beyond bringing the "disabled" closer to the "standard." Such technologies will support people such that they may live with their differences and develop the positive aspects of a diverse society.

Recent attempts to support the diversification of humans and society have included augmenting the body and senses using robotics and information technology [18]. However, the "transformation of one's body image" brought about by augmenting the body has not been sufficiently studied thus far. Human augmentation often implies expansion, ascent, enhancement, and other positive evolution. As such, many investigations to date has focused on this aspect of human augmentation. However, negative effects of body augmentation, such as "contraction," and transitions between state of expansion and contraction must also be considered. In the same way that gene editing has been the subject of social debate, there is a need to elucidate the mechanisms and examine the ethical validity of body augmentation. In order for people to live together, accepting and welcoming their differences, in the cyber-physical society[1] that lies ahead of the fourth social structural revolution, it is necessary to conduct a comprehensive study of the various ways humans exist and interact with their information environment and to explore a new body forms which can allow humans to thrive.

1.2 JIZAI Body & JIZAI State

In this paper, we propose "JIZAI Body," the concept of a computer / machine mediated human body which allows each member of society to adapt to changes in social structure. Such a body is approaching realization in today's ultra-smart society, where diversity is respected and various technologies for human expansion are developing rapidly. The descriptor for this body, "*jizai*" (a Japanese term), originates from the Sanskrit word, "*isvara*," which means supreme being. In Japanese, this term refers to being free from earthly desires and constraints. As such, one who owns a JIZAI Body would not only have and be able to use additional or altered body parts which allow them to live free of constraints. One would also internalize the modified body as part of their own body image, such that the additions/alterations would feel as much their own as their original body (i.e., they would be in a JIZAI state).

This approach is in contrast to current trends towards automation. Today, automated devices are being introduced to conduct tasks which are undesirable to humans. These include tasks with extreme physical and mental strain which need to be carried out in dangerous environments that are detrimental to human health. This approach seeks to remove the human from the task entirely. In the JIZAI state, people can freely use their bodies (and any augmentations), switching between automatic and manual operations at will. This approach can allow people to act freely while maintaining their sense of agency, becoming "human-machine units" with integrated robotic technologies and artificial intelligence. An example would be a car in which a driver can freely switch between automatic, manual, and self-driving modes.

It should be noted that one's own natural body is, in a way, the original JIZAI Body. Human beings acquire a variety of movements and learn to move and feel ownership over their own bodies through physical learning at an early age [9]. On the other hand, the degree to which one is able to enter a JIZAI state with their own body is varied. Not everyone is capable of acquiring the extreme bodily control of an athlete, and the longer we live, the more flexibility and control we lose over our own bodies due to aging. This research aims to provide an opportunity for everyone, from the so-called healthy, to the sick and handicapped, to athletes and musicians with a high level of physical control, to the elderly who have difficulty using their own bodies freely and actively, to free themselves from physical constraints and achieve voluntary self-realization and expression.

Norbert Wiener, a proponent of cybernetics, pointed out that there are two types of things in the world: things humans can control and ones they cannot. Additionally, it was originally said that these things could not cross the boundary between them [102]. We call this boundary between the controllable and uncontrollable the "Wiener-boundary." One definition of the state of owning a JIZAI Body is the state in which one can freely change this boundary

[1] There are several expressions such as "Society 5.0" in Japan and "Industry 4.0" in Germany.

at will, dynamically moving things under their own control or out of it. Considering philosopher Daniel Dennett's suggestion that, "I am the sum total of the parts I control directly," [12], the JIZAI state could also be defined as the state of being able to freely move the boundary that separates oneself from everything else.

In this sense, the scope of research into the JIZAI Body, investigating how one can achieve free movement of the Wiener-boundary, is broad. It includes investigation into various conditions (JIZAI states) in which one can freely control the body parts one is born with (and which may have changed due to growth, aging, accidents, etc.), robotic body parts one might be wearing, the environment one is surrounded by, and one's own mental and physical state (such as in waking, sleeping, or powerfully working).

In addition to overcoming the Wiener-boundary, another key feature of the JIZAI Body is that it allows one to operate both his/her original body parts and additional or alternated ones simultaneously. Current human augmentation technologies mainly focus on enhancing or empowering the existing human body, instead of adding novel functions to the physical body. As mentioned, the JIZAI Body will provide a way of freely controlling the Wiener boundary. This is not limited to expanding the controllable region to include one's environment, but also includes shrinking the region to exclude our own original body parts, allowing one to configure whether they are operated voluntarily.

In this paper, we propose the concept called "JIZAI Body," illustrate how one approaches constructing a JIZAI Body, and forecast directions for a JIZAI Society in which people use JIZAI Bodies to adapt to daily life, each in their individual way. In detail, we provide a literature review to elucidate the position of the JIZAI Body with respect to prior work. Then, we introduce what we consider to be the five key aspects of the JIZAI body, providing several examples of existing works seeking to realize them (Figure 2). Finally, we present several scenarios showing how JIZAI Bodies will contribute to people in the real world. Overall, we would like to claim that being in a JIZAI state, where one owns a JIZAI Body, is a preferred state to achieve when realizing human augmentation.

2 THEORETICAL FRAMEWORK OF JIZAI BODY RESEARCH

While the concept of JIZAI Body is expected to primarily contribute to the field of human augmentation, it is ultimately a multidisciplinary concept which has multiple related research fields including robotics, virtual reality (VR), neurological/cognitive/behavioral/social sciences, humanities, and Human Computer Interaction (HCI) in general. From the concepts of a Cyborg and Cybernetics proposed in the 1960s, to the most recent human augmentation technologies made possible by advances in sensor/actuator/control techniques, machine learning, and other computing technologies, the JIZAI Body draws from and is contextualized in relation to these works. In terms of constructing a JIZAI Body in particular, the scope of existing work that must be referenced is not limited to robotic techniques for physically generating additional body parts, but also includes VR related techniques for constructing virtual bodies. In terms of furthering our understanding of the JIZAI state, how one adapts a JIZAI Body in the physical and/or virtual world, we reference and make use of various scientific methods in the fields above and additionally consider methodologies used in the humanities and social sciences. In this section, we review previous works to contextualize our proposed concept, elucidate its contributions, and introducing methods and approaches related to constructing a JIZAI Body and understanding the JIZAI state.

2.1 Fundamentals of JIZAI Body: Cyborgs, Human Augmentation, and Cybernetics

In its natural state, the human body is less JIZAI than one might believe. Most humans (even experienced athletes, dancers, musicians) are not capable of controlling their body to perfectly achieve the results they desire at all times. Multiple approaches have been taken to overcome this, including augmenting one's abilities through the use of tools, and more recently, machines. However, it has been suggested that these machines are integrated into the self as one uses them, changing them from being mere tools to being part of one's body. This suggestion has existed since long before any formal studies were conducted into the matter. For example, Robert Hooke, a 17th century English researcher, wrote in the introduction to his book *Micrographia*, describing the discovery of the cell, that "while man has imperfections in sensation, memory, and reason, one may compensate for shortages in perception through artificial organs such as optical devices" [31].

This idea of human-machine integration was given the name "cyborg" by the Austrian inventor Manfred Clynes and the American scientist Nathan Clyne in 1960 [11]. In the midst of the space race, in an article entitled "Cyborgs and the Universe," they proposed the concept of expanding the scope of human activity beyond Earth by physically enhancing the body. Today, there is a field of research dedicated to understanding and enhancing the human body through technological augmentations.

Research relating to the development of cyborgs is often referred to as the field of human augmentation. Approaches to augmentation are highly varied and include both perceptual and action augmentation for a variety of purposes. Some works seek to augment one's skills by teaching them to the existing body through skill transfer [52], direct muscle stimulation[39], and sports design[72]. Other works seek to augment one's abilities by modifying one's existing abilities through technological means. Some examples include augmentation of the senses of sight [29, 35, 40, 51] and smell [7], and capabilities like vocalization [50, 60] and manipulation [95]. Yet other works have sought to augment internal elements of the human being, such as interpersonal perception and emotion [71, 92, 106, 107]. More recent research has sought to reach a deeper level of integration between man and machine to achieve greater levels of augmentation [69]. However, this does not guarantee free and effective use of the augmentations. This is especially true when the augmentations in question grant the user additional capabilities instead of extending pre-existing ones (e.g., augmentations that grant an additional limb instead of making existing limbs stronger).

An approach to promote effective use of such augmentations can be formulated by referring to the field of cybernetics. This field, established by Norbert Wiener in 1948, is the study of communication and control, both in humans and, in a broad sense, the machines they use [102]. One concept introduced by this field is that of controllability. Wiener suggested that elements of a system can be categorized into those that can be controlled and those which are uncontrollable. This is a hard classification which differentiates based on whether it is *possible* to control the element. However, controllable elements of a system regularly pass in and out of direct (conscious) control of the system. In the natural human body, for example, limbs and other functions smoothly transition from being under conscious control to under semi-automatic control. This capability allows one to achieve a high level of physical control and parallelization with minimum cognitive load. Being able to apply this free and willful control of controllability to things beyond our natural body and allowing elements which are typically uncontrollable into the domain of being controllable could facilitate effective use of the extended (augmented) human body and expansion of our understanding of what one might consider one's own body. Enabling this free and willful movement of elements into the controllable domain is the approach embodied by the JIZAI body.

The concept of JIZAI body is a natural next step in the evolution of the human body and human augmentation. It is a user centered design philosophy which emphasizes the ability to seamless transition between a controllable and uncontrollable state, just as one may seamlessly transition between conscious and unconscious control of their natural body. The fields we draw from in order to realize a JIZAI body are similar to the fields that the field of human augmentation draws from. However, a heavier emphasis is placed on simultaneous and independent control of augmentations and extensions of the natural body and the use of virtual elements which free the body from the limitations put in place by the laws of physics.

2.2 Constructing a JIZAI Body

To generate and allow embodiment of a JIZAI Body, engineers and designers need to focus on both physical and virtual body development. Humans nowadays have a presence not only in the physical world but also the virtual world, such as in the VR communities. Furthermore, we need to focus on bridging physical and virtual world, which has already been discussed, for example, in remote communications. Herein, we provide an overview of the work which forms the basis upon which the development of JIZAI Bodies is built.

2.2.1 JIZAI Body in Physical World. In terms of physical development, robotic technologies have been widely applied to physically augment the human body. Robotic exoskeletons, for example, have been used to enhance the physical strength and robustness of the existing body [8, 41–43, 101]. Robotic doubles which a human can remotely embody have allowed one to fundamentally change the body's properties and its composition [2, 15, 58, 89]. Many of these works, however, remain bound to the bipedal human form. They either enhance what already exists or reflect the motions of the natural human body.

More recently, efforts are being made to change the human form altogether through integration with robotic technologies. One example is a class of robotic attachments known as supernumerary robotic limbs (SRLs) which provide individuals with additional limbs (most commonly arms) [14, 36, 78, 79, 83, 85, 94, 96]. Other examples include additional fingers [47, 82, 98] and tails [62, 103]. Such hardware has shown the potential for practical augmentation of the human form through robotics.

However, there remain issues associated with bringing such an augmented form into more general use. Chief among these are designing a control interface for enabling free control of the robotic augmentations. This is especially true for robotic augmentations which result in a body form with more degrees of freedom than the natural body has to begin with (e.g., supernumerary robotic augmentations). The need to control additional degrees of freedom while, ideally, not sacrificing the freedom of the preexisting body poses a challenge. Approaches proposed to achieve parallel operation include semi-autonomous control and exploiting redundant degrees of freedom in the existing body. An example of the former is found in [63], where a robotic hand autonomously determines when to let go of a ball while being swung by a human arm. An example of the latter is found in [90], where a robotic arm, finger, and tentacle were controlled through shoulder motions to not interfere with manipulation tasks. Both work towards achieving free and at-will control of an augmented body with additional degrees of freedom.

It should be noted, however, that the application of such approaches to controlling an augmented body is not limited to the physical body and augmentations of it. The same principles apply for virtual extensions of the existing body. This has become more apparent with the spread of VR technologies, which allow one to feel a bodily connection to virtual worlds.

2.2.2 JIZAI Body in Virtual World. From the beginning, VR was seen as a means to experience constructed worlds. Starting with Ivan Sutherland's invention of "Ultimate Display" (a head-mounted display; HMD) in 1968, which allowed people to experience a world built inside the computer [91], there have been many works seeking to allow one to experience a reality that does not physically exist. This is typically achieved by using sensors to capture human body movements and present sensory information such that a user feels they inhabit the environment they are presented. For example, gloves that measure the position and movement of the hands and fingers, suits and body-mounted tracking devices that measure the movement of the whole body, and treadmills to acquire walking motion are used in conjunction with stimulus presentation devices such as HMDs that present audiovisual information which makes one feel as if they are in the virtual environment and have a virtual body. A wide variety of devices have been proposed to capture human movement and provide stimulus such that one may become immersed in a virtual world.

Compared to the early days of VR, VR both more accessible and popular due to the associated hardware devices becoming less expensive and easier to obtain. Simple VR setups such as the HTC VIVE[2], Oculus[3], and smartphone-based HMDs are now available at consumer electronics stores, making it easy to experience VR at home without the need for a specialized facility. In addition, software for creating virtual worlds[4] and bodies (avatars)[5], platforms for distributing and providing virtual worlds to users[6], and image processing techniques allowing one to bring physical objects, including oneself, into the virtual world as a three-dimensional

[2]https://www.vive.com/us/product/vive-pro2-full-kit/overview/
[3]https://www.oculus.com/quest-2/
[4]https://unity.com
[5]https://vroid.com/en
[6]https://cluster.mu/en

object[7] are becoming increasingly available. As such technologies and hardware become more commonplace and attainable, VR has grown to become an accessible immersive prototyping platform wherein one can freely edit their own body and environment to their own liking.

Digitization of both the body and environment gives one the ability to freely edit their own physical appearance, capabilities, and properties. Such transformations have been found to induce changes in how we behave and think. This phenomenon, in which one's physical appearance (avatar) induces changes in cognition, behavior, attitude, and thought, is known as the "Proteus effect" [104]. For example, it has been reported that people who had VR experience of flying like a superhero were more likely to encourage prosocial behavior [81], and that using an elderly person's avatar in VR reduce negative stereotypes toward the elderly [105].

VR also has the potential to provide experiences that go beyond transformations and achieve new body forms. For example, VR can realize the experience of controlling multiple bodies (e.g., clones of oneself) [28, 88], allowing multiple people to inhabit a single body [20], and leaving one's own body as if having an out-of-body experience [6]. Research on the transformation of human cognition and abilities through such bodily experiences is being conducted from a variety of perspectives.

Even more so than robotics, VR presents innumerable possibilities for augmenting the human body. Without the limitations of physics, the only limitations to what forms one can achieve is one's own imagination. One may even rapidly transition between multiple body forms at will. This suggests that VR, which allows one to edit their body and environment freely, is an ideal approach to constructing a JIZAI body and investigate the JIZAI state. However, control of such novel body forms and movement between forms still remains a topic in need of investigation. Furthermore, the virtual body need not be considered a reflection of the physical body. Namely, as discussed in our review of the robotics literature, the virtual body could be considered an extension of the physical body. As such, being in a JIZAI state should allow for free and at-will control of both the physical and virtual body simultaneously. Thus, while construction of a JIZAI body is one of the paramount objectives of this line of research, it is equally essential to understand the JIZAI state and how one might go about achieving it such that they may effectively use a JIZAI body.

2.3 Understanding the JIZAI State and Societies

2.3.1 Scientific Methods. To understand the JIZAI state, it is necessary to focus on how humans adapt to JIZAI bodies constructed using the above-mentioned robotic and VR technologies. Adapting to an artificial body and experiencing the sensation of it "being the same one's own body" is commonly referred to as a sense of embodiment (hereafter embodiment) [49]. Therefore, to develop JIZAI Bodies that can result in the attribution of situations experienced through the artificial bodies to oneself, it is necessary to understand the mechanisms of embodiment and consider them in their design.

[7]https://itseez3d.com

Previous works studying human augmentation with respect to the neurocognitive sciences have discussed embodiment from several perspectives. A sense of body ownership (i.e., the sense that an object is a part of one's own body), a sense of agency (i.e., the sense of controlling one's own actions), and a sense of self-location (i.e., the determinate volume in space where one feels to be located) have been the focus of many studies as representative factors that compose the sense of embodiment [22, 49]. In addition, the expansion and contraction of peri-personal space (i.e., the area surrounding of the body in which stimuli from the external world can be directly perceived) has also attracted attention as a perceptual transformation of self-consciousness closely related to embodiment [4, 30, 73, 87]. Other methods of examining and evaluating embodiment include psychometric scales, physiological responses, behavior, brain activity, and combinations of these.

Using the above-mentioned evaluation methods, previous studies have investigated and suggested key factors contributing to enhancing the sense of embodiment. For example, sensory integration and sensorimotor integration are essential mechanisms for achieving the embodiment [16]. Thus, it is difficult to achieve embodiment when stimulus presented to artificial body parts (mainly visual feedback) is not consistent with sensory feedback (e.g., tactile, haptic, and proprioceptive) perceived through the natural body. It is also known that the sense of body ownership is restricted by spatial and anatomical consistency[17, 34, 97].

On the other hand, previous studies on bodily illusions and tool incorporation have supported the applicability of embodiment to artificial objects and tools that do not completely overlap with the natural body in shape [49], appearance [19, 48, 77], and size [100]. In addition, it has been suggested that embodiment can occur in various alternative body parts such as hands [5], legs [80], fingers [46], and the whole body [59]. These works demonstrate that humans have the potential to embody new body parts which are different in form from their existing body. However, the degree of embodiment and time required for the embodiment may differ depending on the consistency between artificial and biological body [3, 19, 44]. Thus, when developing JIZAI Body that provides previously impossible experiences using artificial bodies constructed using robotics and VR, as described in section 2.2, it is necessary to consider how to enhance the sense of embodiment in the artificial body. For example, when developing a JIZAI Body that augments the user's physical movements, it would be necessary to design a way to compensate for spatio-temporal conflicts between the user's own movements and those of the JIZAI Body (e.g., by gradually changing the degree of intervention [38]).

In this way, measuring and understanding the mechanisms underlying the embodiment of an artificial body is essential for understanding the JIZAI state. Furthermore, it is important to develop a JIZAI Body that can enhance embodiment based on neurological and cognitive findings.

2.3.2 Phenomenological Methodologies. In addition to the scientific methods described above, there is a need to adapt subjective research methodologies used in the humanities and social sciences to understand social, cultural, aesthetic, and ethical phenomena which will result from the introduction of JIZAI Bodies. Such investigations will provide an understanding of how JIZAI Body and

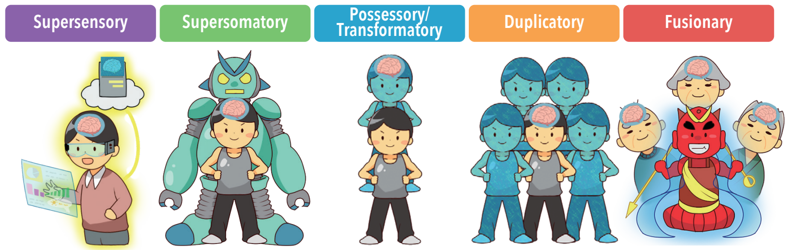

Figure 2: Five key aspects of JIZAI Body

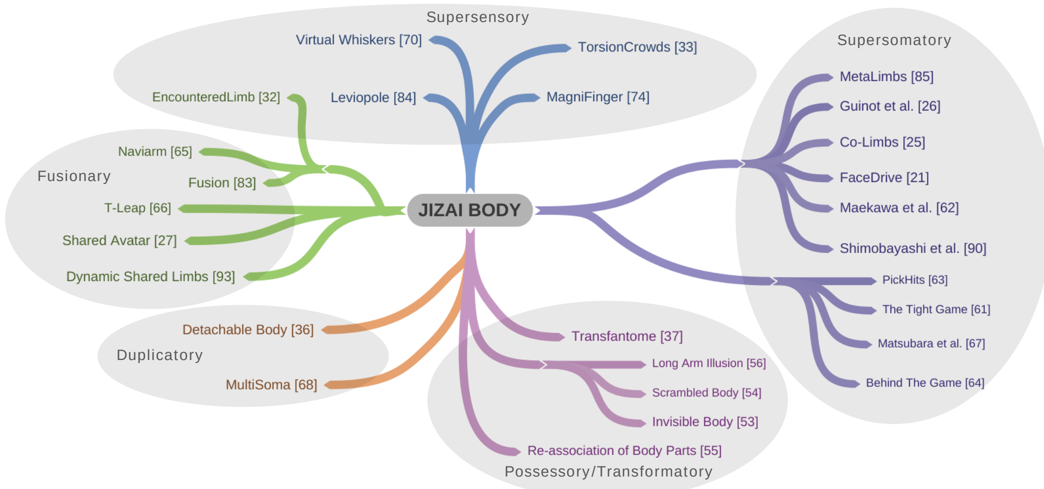

Figure 3: Previous works to build JIZAI Bodies [21, 25–27, 32, 33, 36, 37, 53–56, 61–68, 70, 74, 83–85, 90, 93]

JIZAI state are perceived and could be accepted by society. To capture how one might experience JIZAI in the real world, long-term research, (e.g., [75]) including autobiographical studies [13] which are suitable for personal, sensitive, and/or private reflections, will be required. Such methods are, as of the current state of the literature, mostly employed in the HCI design community. As suggested by Kieliba et al. [47]'s recent result, which were achieved after a 5-day experiment, scientific studies are gradually shifting to focus on longer-term studies. Such longer term studies have the potential to provide insight into the societal and cultural impacts of introducing new technologies [75, 76]. Conducting longer-term studies utilizing phenomenological methodologies based on ethnography, observation, cultural probes [23], and autobiographical approaches may, thus, reveal future directions which lead to the development of JIZAI Bodies with strong social and cultural impacts.

As described in this section, JIZAI Body is defined as a preferred state of adopting emerging technologies for human augmentation. A JIZAI Body is not just a cyborg body, but is a body in which one has the flexibility to control the Weiner boundary. It is a body with the ability to seamlessly transition parts of it between controllable and uncontrollable states, just as one may seamlessly transition between conscious and unconscious control of parts of their natural body. To construct a JIZAI Body, one must not only use HCI technologies, but also employ robotics and VR technologies. To understand the JIZAI State, one must widely refer to scientific methods such as those used in the neurocognitive sciences. Finally, to understand the everyday and cultural impacts of JIZAI Body in the real world, one must make use of phenomenological methodologies and conduct long-term user studies. In this paper, we introduce key aspects of a JIZAI Body through existing examples and attempts to realize JIZAI Bodies. Additionally, we present real-world scenarios in a future where people have acquired JIZAI Bodies. While many of these have yet to be validated by the research methods described in the literature review, the following sections reinforce the motivation of this paper's proposal of the JIZAI Body concept and the need to develop and understand it.

3 FIVE ASPECTS OF JIZAI BODY

Herein, we suggest that there are five key aspects to JIZAI Body, Figure 2: *Supersensory*, *Supersomatory*, *Possessory/Transformatory*, *Duplicatory*, and *Fusionary*. In this section, we introduce these five aspects and illustrate them through existing works. It should be noted that the list of existing works cited herein is not comprehensive, nor are the works cited for each aspect uniquely classified to that aspect. Works may fulfill multiple aspects of JIZAI Body and combinations of works may allow the fused product to fulfill yet more aspects due to synergies between them. The description and

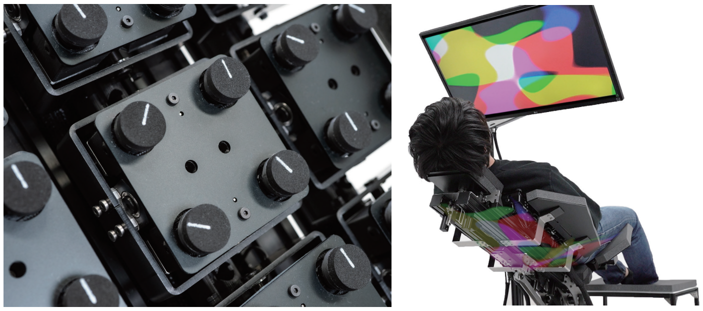

Figure 4: TorsionCrowds [33]

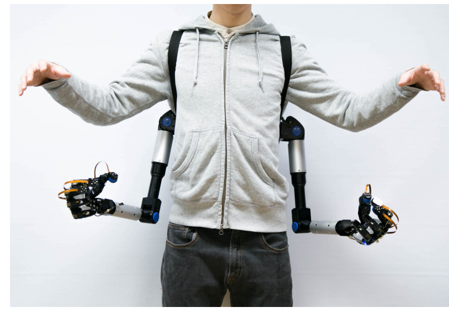

Figure 5: MetaLimbs [85]

Figure 6: Co-Limbs [25]

Figure 7: Sixth Finger [98]

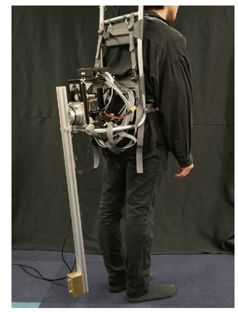

Figure 8: Tail-like balancer [62]

illustration provided herein serve as an overview. A selection of the works are summarized in Figure 3.

3.1 Supersensory

The *Supersensory* aspect of JIZAI Body focuses on expanding human sensory capabilities, such that one may sense information that is difficult to perceive and recognize due to physical and cognitive limitations. It not only allows one to experience a more vibrant and daily life colored by novel sensations, but could also improve one's information processing and motor abilities, and enhance one's awareness and immersion in virtual environments.

One example of such works is, TorsionCrowds, a distributed haptic display that uses multiple rotating contactors to cause shear deformation in a user's skin [33] (Figure 4). It is capable of presenting continuous information over a wide area of the body with a higher dynamic range than existing tactile presentation methods. Another example is, LevioPole, a tactile force presentation device that uses propeller thrust [84]. It can be used in conjunction with VR content that involves full-body movement due to not being grounded, and has been confirmed to enhance the immersion in virtual experiences.

3.2 Supersomatory

The *Supersomatory* aspect of JIZAI body extends one's abilities and functions beyond the constraints of the natural body using robotics and HCI technologies. It also explores how humans can use newly acquired artificial body parts and abilities, as well as how the user's behavior can be transformed by their acquisition.

A typical example of a *Supersomatory* JIZAI body is achieved by extending the physical form of the body through the use of wearable robotics and devices. For example, there are works on designing and controlling a third or fourth arm. These arms can be used to assist the wearer in performing tasks around them, or to understand to what extent the new arm can be manipulated at will. However, as noted in the literature review, when artificial body parts are added, the first major problem which arises is how to control the body parts. Multiple solutions have been proposed over the years. MetaLimbs [85] (Figure 5), for example, directly maps the motion of both feet to two robotic arms. Co-Limbs [25], applies admittance control (Figure 6), allowing the arms to be moved to a location and held in place. FaceDrive [21], controls arms using facial expressions. Finally, other work has proposed a method using redundant degrees of freedom in the shoulder to control arms while performing manipulation tasks [90].

In addition to the aforementioned artificial arms, research is also being conducted on the enhancement of physical capabilities and transformation of body image by adding a robotic sixth finger [98] (Figure 7) or a tail-type device [62] (Figure 8) to the natural human body.

3.3 Possessory/Transformatory

The research on the *Possessory/Transformatory* aspect of JIZAI Body focuses on allowing one to transcend the limits of their own body and seeks to elucidate the limits of what we may consider as being part of ourselves. In particular, the former allows one to exit and enter bodies at will, even existing without any body at times. The

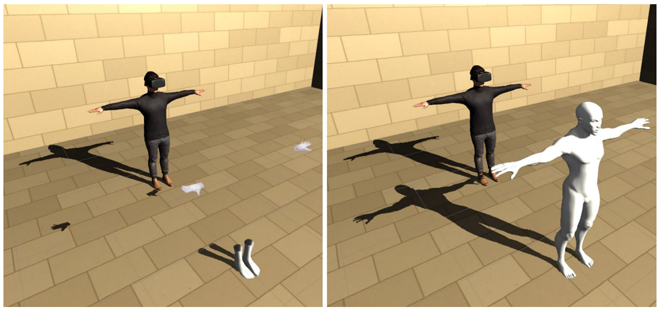

Figure 9: Invisible body [53]

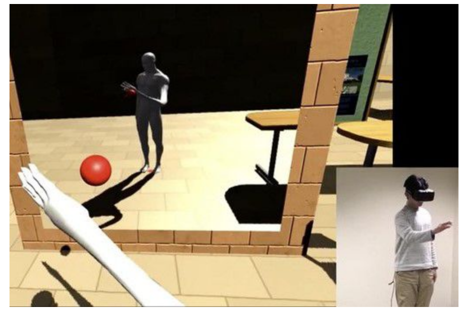

Figure 10: Long arm body [56]

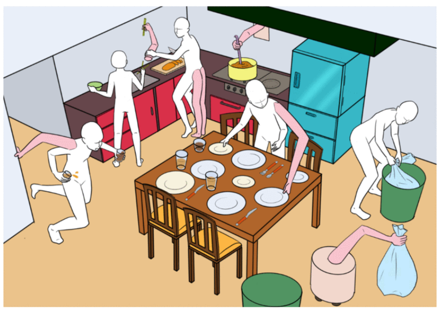

Figure 11: Detachable Body [36]

Figure 12: MultiSoma [68]

Figure 13: Fusion [83]

latter, in comparison, allows one to modify the limits of the existing body, deforming it from its natural state.

An example of research on the *Possessory* JIZAI Body can be seen in Transfantome. In this prototype, one can virtually transfer between two robots of different sizes, which are in two different positions, to perform a single [37]. The experience of transferring between the two robots is generated by superimposing a virtual avatar on the workspace and adding visual effects during the transition which emphasize motion from one robot to the other and a change in size.

In terms of the *Transformatory* JIZAI body, research has been conducted exploring the extent to which one can feel that a modified version of their body (in both appearance and motion) remains their own body. For example, investigations have shown that a sense of body ownership is maintained for a transparent body [53] (Figure 9) and a body with an arm significantly longer than those found on a natural body [56] (Figure 10). The latter work has also shown that human behavior changes when given the new body, shedding light on how transformations and behavior changes are linked. Namely, it showed that, when one arm is longer than the other, the operator gradually uses the longer arm more than the normal length arm in a reaching task.

3.4 Duplicatory

Research into the *Duplicatory* aspect of JIZAI Body aims to allow one to exist and operate across spatio-temporally separated spaces or operate multiple robots and/or avatars simultaneously. To date, there have been efforts to research duplicatory JIZAI bodies by investigating visual and tactile feedback necessary for supporting the operation of detachable body parts [36] (Figure 11), and by examining the body sensations induced by operating multiple avatars moving in synchronously in virtual space using MultiSoma [68] (Figure 12).

3.5 Fusionary

Finally, the *Fusionary* aspect of JIZAI body enables multiple people to share the same time and space by cohabiting a single body. This can be achieved by, for example, allowing one to latch onto another individual's body or by having multiple individuals contribute to cooperatively controlling a single robot or avatar.

An example of the former is "Fusion," a system that uses a wearable robotic arm and a visual presentation device to allow two distant people to share a workspace and work together cooperatively [83] (Figure 13). An example of the latter is a VR-based system which allows two individuals to share one avatar to perform full body motions [27]. Experiments conducted with this system have shown that the movements of the shared avatar are straighter and smoother than when the operators work individually, suggesting the possibility of attaining new physical capabilities through body sharing.

4 PROSPECTS FOR JIZAI SOCIETY

4.1 Automation and JIZAI

Today's rapid development of self-driving cars is a representative example of the recent trend towards "automation," where robots do things that humans do not want to do. This is distinct from the concept of JIZAI proposed in this paper. The most important

(a) Pick Hits [63] **(b) The Tight Game [61]**

Figure 14: Human-machine mutual actuation in sports

characteristic of a JIZAI society, where people with JIZAI Bodies re commonplace, is that each person can freely do what they want to do without being constrained by their physical characteristics or limitations. Namely, while liberating people from their "not wants" might at first glance seem similar to allowing people to do what they "want", this is not always the case. For example, while automated driving technology may feel liberating to those who do not enjoy or want to drive, it is not a liberalizing technology for those who like to drive. Rather, it acts as an inhibiting technology to those who would rather drive themselves. Presenting an automated experience as the only option is not a flexible state. A JIZAI experience, in contrast, allows the car to be driven as the driver wills, whether that be automatically, manually, or anywhere in between. In this section, we will look at the experiences and values that a JIZAI society will provide, comparing them with automation technologies that are already in widespread use.

4.2 Application to Sports

Sports or sports science is an area where the results of research on the JIZAI body can be immediately applied. The "Bubble Jumper" [8], "Hovercross" [9], and "Cyber Wheel" [10] events under development in the "Superhuman Sports" Project are prime examples. These events are competitions in which people make full use of their bodies in a JIZAI manner while expanding their physical capabilities through the use of technology. Research on JIZAI Body and the JIZAI state have served to inspire these events.

In more traditional sports, investigation into JIZAI body can contribute to improving control over one's own natural body. It is extremely difficult for even highly sophisticated athletes to perceive their own body movements accurately and control them freely. Some research assists with more accurately perceiving one's own body in order to better control it. For example, devices, such as the JINS MEME eyeglasses [57], which can measure ocular muscle potentials, can assist with visualizing one's own running form and immediately recognizing shifts in one's posture[11]. Other works are exploring methods of directly acting on and "controlling" the body, such as through the use of muscle potential stimulation [67] and human-machine mutual actuation [61, 63] (Figure 14).

[8]https://superhuman-sports.org/sports/bubblejumper.php
[9]https://superhuman-sports.org/sports/hovercrosse.php
[10]https://superhuman-sports.org/sports/cyber.php
[11]https://www.youtube.com/watch?v=f9ihBV06iM4

4.3 Rehabilitation

The JIZAI technology for assisting visualization and accurate control of body movements mentioned above is additionally expected to be used in the rehabilitation. For example, it may be used to help in the recovery of motor functions in stroke patients. For example, in patients with hemiplegia, one of the after-effects of a stroke, have difficulty walking while maintaining balance. JIZAI technology could be used to develop a system which initially allows the patient to move by forcibly moving their limbs at first and then in response to the patient's own voluntary movements as they recover motor functions, as if assisted by a physical therapist.

LevioPole [84], a force-feedback device that uses propeller thrust, could, for example, be used to help reacquire a sense of balance. As mentioned above, such technology can be very useful for enabling "one to use their own body to do what they want to do". As seen in these first few application areas, the same basic technologies for enabling a JIZAI body and entering a JIZAI state can be applied to achieve a variety of results across application such as enabling sports which require extreme body movements and control, daily exercises for healthy people, and rehabilitation to recover lost motor control.

4.4 Artistic expressions with the body

Artistic expressions that involve physical movements, such as plays and musical performances, can also make use of the JIZAI body and JIZAI technology. The Robotic Musicianship Project of the Center for Music Technology at Georgia Tech studied the use of robotic arms and hands to play the piano and drums. In the drumming project, a drummer who lost his hand due to an accident wore a special device that allowed him to play using EMG (myoelectric input), [24], and another drummer equipped with a third arm played a set of drums that could not normally be played simultaneously [45]. These two examples are representative of the two types of artistic expression which can be created using JIZAI technology: prosthetic and transcendental. The former aims to recover lost functionality using technology, while the latter seeks to transcend the limitations of the body to create completely new forms of expression. Finally, one should note that such use of JIZAI technologies are not limited to superficial body modifications and alterations, but can also applied in a super-sensory sense to allow performances which go beyond the speed limits of cognition and movement (Figure 2).

4.5 Active and Jizai until the end of lives

British scientist Peter Scott-Morgan, who was diagnosed with a terminal condition of Motor Neurone Disease (MND) in 2017, chose to survive as a "cyborg," so to speak, by wearing an "artificial body" constructed making full use of currently available technologies [86]. He connected a small ventilator to allow him to breath, a feeding tube to allow him to eat, a catheter and colostomy to allow him to pass waste material from his body. He removed his pharynx to prevent saliva from entering the lungs, he recorded his voice and used it for speech synthesis, and he uses a virtual avatar to form facial expressions. While suffering from an incurable disease which has a typical life expectancy of a few years, he has, so to speak, chosen to be freed from the limitations of his original body and embrace a mechanical body. The loss of the ability to eat and speak with a human voice is a loss of freedom, and can be seen as a limitation of the technology available today. However, this case is not unique. Every human being is subject to some physical limitations by the end of their life. JIZAI body and the associated technologies have the potential to allow one to be active in society to the end of their life.

In the JIZAI society, even bedridden elderly people will be able to enjoy going out via *Possessory* JIZAI body technologies such as T-Leap [66] and Fusion [83] until the end of their days. A recent article explored the necessity of telepresence/telexistence technologies for supporting remote/virtual funeral attendance in a super-aged society [99]. Such technologies will allow one to keep active in society and provide the variety needed to give one the ability to choose a body which best suits their need.

4.6 Considering Ethical Issues

As the JIZAI body develops beyond only being a topic of research and moves closer to being a part of society, ethical issues will and legislation will become necessary regulating the use of JIZAI technologies. While ethical issues related to artificial intelligence and robotics have already been discussed and debated, the topic of autonomous bodies and technologies in society pose additional challenges. According to a report by researchers at University College London who used a device with a special "third thumb" [47] and arms controlled by input from the feet, much like MetaLimbs [85], the authors raised the issue of the safety of losing an artificially added body part. It is already known that the loss of a specific part of the brain, such as in stroke patients, can cause specific physical dysfunction, but in the future, the acquisition and loss of a JIZAI body part may also result in a change to human brain functions. This may be particularly true in young people with their bodies still in development. It will be necessary to continue research and discussion on the merits and demerits of the acquisition of JIZAI technology.

5 CONCLUSION

This paper proposes the "JIZAI Body" as being one of the preferred states to achieve when designing augmented humans. The JIZAI Sate, in which one owns a JIZAI Body, enables one to simultaneously operate their original body parts and any additional (robotic or virtual) ones as they wish. Namely, it will enable one to control additions to the body as if they were part of the original body.

In one's natural (original) body, there are parts which are controllable and uncontrollable (or difficult to control). One is typically not able to change this classification and, thus, the boundary between the controllable and uncontrollable parts is fixed. Referencing Norbert Wiener's field of cybernetics, the study of control and communication in man and machine, we termed this boundary the Wiener boundary. In a JIZAI Body, one is able to control the Wiener boundary to their benefit in everyday occasions (i.e., to actively work and perform in the society).

To investigate the validity and importance of this proposal, we presented a literature review which focused on contextualizing the JIZAI Body in human augmentation research. It also touched on other overlapping domains such as HCI, robotics, VR, neurocognitive sciences, and the humanities. Additionally, though there is no perfect example of achieving the JIZAI state to date, we introduced prior works seeking to realize JIZAI bodies. These works were introduced with respect to the five key aspects of JIZAI body. Finally, envisioning the JIZAI society in which people adopt JIZAI Bodies in their everyday livings, we introduced multiple scenarios to give a concrete shape to the image of the JIZAI society. The JIZAI Body does not give us a linear augmentation or enhancement of our natural abilities. Rather, it provides a means to be flexible and provide opportunities. It allows one to use one's body and live as they wish.

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