Virtual Avatar Creation Support System for Novices with Gesture-Based Direct Manipulation and Perspective Switching

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Keywords: Virtual Reality, Avatar, Creativity, Gesture-Based Direct Manipulation, Life-Size, First-person Perspective, Third-Person Perspective, Embodied Interaction.

Abstract: Given the increasing importance of virtual spaces as environments for self-expression, it is necessary to provide a method for users to create self-avatars as they wish. Most existing software that is used to create avatars require users to have knowledge of 3D modeling or to set various parameters such as leg lengths and sleeve lengths individually by moving sliders or through keyboard input, which are not intuitive and require time to learn. Thus, we propose a system that supports the creation of human-like avatars with intuitive operations in virtual spaces that is targeted at novices in avatar creation. The system is characterized by the following two points: (1) users can directly manipulate their own life-size self-avatars in virtual spaces using gestures and (2) users can switch between first-person and third-person perspectives. We conducted a preliminary user study using our prototype. The results indicate the basic effectiveness of the proposed system, demonstrating that substantial room for improvement remains in the guide objects that are used to manipulate the manipulable parts.

1 INTRODUCTION

Research on the application of computer technology in creative contexts has been conducted for many years. However, tools that make use of advanced technology do not fully activate human creativity and sensitivity, but rather, inhibit them (Black, 1990). When users hold a mouse or keyboard that is capable of precise and detailed information input, and view a precise and well-ordered objects on a display as small as 20 to 30 inches, they become absorbed in the details and fall into mere "tasks." As a result, an important thoughts, that of developing an overall mental image of the desired creation and making bold alterations to the creative work, can be lost. This leads to a design that is superficially pretty but lacking in content and substance (Tano, 1999).

On the other hand, embodied interaction is attracting attention as a field that combines body, mind, cognition, and emotion when people interact with a digital environment (England, et al., 2009). In Where the Action Is (Dourish, 2001), Dourish states that while our bodies are our most familiar presence, it is a presence that is difficult to consider objectively; consequently, interaction design has mainly been based on the Cartesian principle of the mind–body dichotomy. He stated that future interaction design should carefully consider users' Heideggerian state of immersion in the everyday world, namely embodiment, and that digital technology must be used appropriately. That is, embodiment means not only the body itself, but also a wide range of suggestions including emotions, feelings, intuition, etc. that arise through the body. Therefore, in a digital environment that is designed with embodiment in mind, the user experience will rely on rich mappings among the physicality, body gestures and movements, tangible artifacts, and interface, resulting in experiences that relate directly to the feelings and actions of users.

In this study, we explored the possibilities of embodied interaction in a creative context — virtual avatar creation. Avatars are used to alter the egos of real-world users in virtual spaces. Two main means are available for users to obtain their own avatars: purchasing off-the-shelf avatars and creating their own avatars. Users may be unable to purchase an ideal off-the-shelf avatar. Moreover, most existing avatar creation software require users to have

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knowledge of 3D modeling or set individual parameters such as the leg length and sleeve length by moving sliders or through keyboard input, which are not intuitive and require time to learn. This may be a barrier for users who wish to create and personalize their own avatars (Freeman, et al., 2020).

Thus, we propose a system that supports the creation of human-like avatars through intuitive operations in virtual spaces. Specifically, (1) users can directly manipulate life-size self-avatars in virtual spaces using gestures and (2) users can switch between first-person and third-person perspectives. The target users are novices who are beginning to take an interest in avatar-creation.

2 RELATED WORK

2.1 Studies on Automatic Generation of Virtual Avatars

Various methods have been proposed for the automatic generation of virtual avatars, e.g., (Ichim, et al., 2015; Nagano, et al., 2018; Li, et al., 2019; Murthy, et al., 2021; Hu, et al., 2021). The majority of these methods use photographs of the users as input to reproduce their real-world appearance in the virtual world (Ichim, et al., 2015; Nagano, et al., 2018; Li, et al., 2019; Murthy, et al., 2021; Hu, et al., 2021) or to emphasize the features of their real-world appearance (Hu, et al., 2021). Although techniques based on automatic generation offer the advantage of rapid and efficient avatar creation, avatars that are desired by the users cannot always be generated. Given the increasing importance of virtual spaces as environments for self-expression, it is necessary to provide automatic avatar generation from user photographs as well as the creation of avatars that are desired by users through interaction between the user and system. However, to date, limited research has been conducted in this area.

2.2 Software to Support Creation of Virtual Avatars

We analyzed existing software that are available for virtual avatar creation and divided them into four types, as detailed in the following sub-sections. All the types enable users to create avatars while interacting with the system.

2.2.1 3D Modeling Software

Blender (blender.org, 2022) and Metasequoia4 (tetraface Inc., 2022) (Figure 1, upper left) are software programs that can create 3D models in general, including virtual avatars. These programs enable users to create avatars with complex shapes that are difficult to create with other software types, and thus, offer a high degree of freedom in the creation.

However, several challenges exist: knowledge of 3D modeling is required; the operation is complicated; and it is difficult to imagine the shape, thickness, and size of the 3D avatar on a 2D display, and ultimately, how the avatar will be represented in virtual spaces.

2.2.2 Avatar-Creation Software for Desktop PCs

VRoid Studio (Pixiv Inc., 2021) (Figure 1, lower left) is an example of software that is specialized for avatar creation on desktop PCs. In VRoid Studio, users generally adjust the parameters relating to the shape of the avatar by moving the slider or entering numerical values using the keyboard. Users can select parts or draw hairstyles, faces, and clothes directly using a tablet pen. Although the degree of freedom offered is slightly lower than that of the aforementioned 3D modeling software, the operation is less complicated.

However, the limitations are as follows: numerous parameters need to be adjusted; it is difficult to map the parameters to the avatar geometry; and it is difficult to imagine the shape, thickness, and size of the 3D avatar on a 2D display, and ultimately, how the avatar will be represented in virtual spaces.

2.2.3 Avatar-Creation Software for Smartphones

Software that is specialized for avatar creation on smartphones includes Custom Cast (Custom Cast Inc., 2018) (Figure 1, right). In Custom Cast, users select body parts to create and adjust the shape using slider operations. As with the avatar creation software for desktop PCs described above, the complexity of the operation is not very high.

However, the difficulties are as follows: it is cumbersome to operate the entire app using fingertips on a small screen (i.e., the fat finger problem); and the small screen makes it more difficult than with software for desktop PCs to imagine the shape, thickness, and size of the 3D avatar, and ultimately, how the avatar will be represented in virtual spaces.

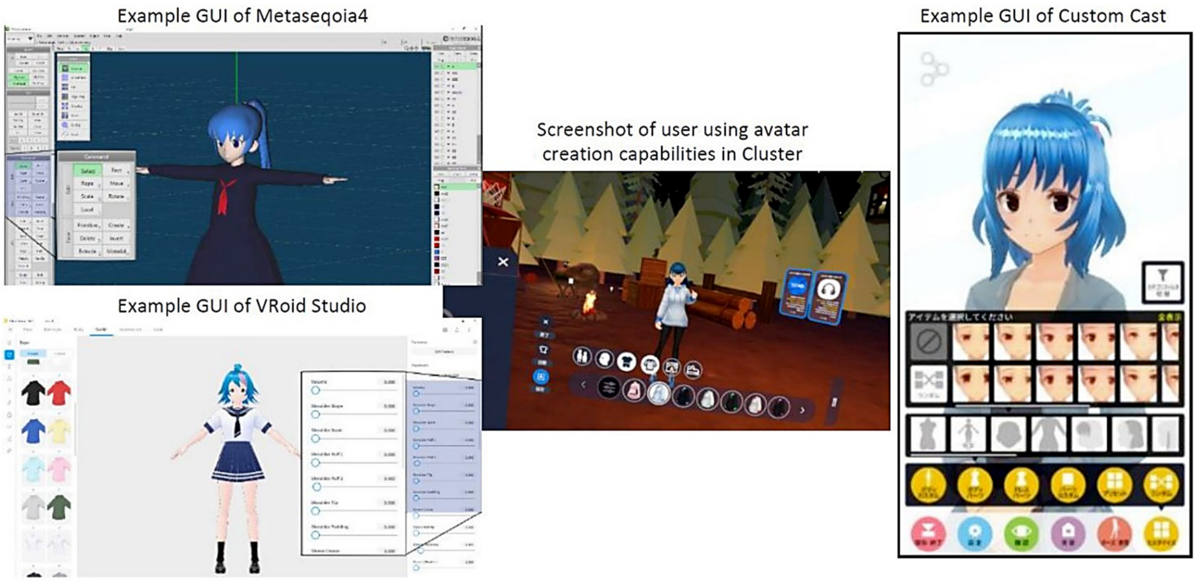

Figure 1: Examples of existing software for virtual avatar creation.

2.2.4 Avatar-Creation Capabilities on Social Virtual Reality Platforms

Cluster is an example of a social virtual reality (VR) platform with avatar-creation capabilities (Cluster Inc., 2017) (Figure 1, center). Cluster enables users to select costumes in virtual spaces for the default avatar and adjust the avatar shape using slider operations. The interface is similar to that of avatar-creation software for smartphones. In the software that was described in the previous three sub-sections, users view and create their avatars on a 2D display (i.e., third-person perspective), whereas Cluster allows users to view and create their avatars in virtual spaces (i.e., first-person perspective).

However, the interface for creating avatars is almost the same as that of the avatar creation software for smartphones, which is not necessarily optimal for creating avatars in 3D space. Moreover, although Cluster supports both third- and first-person perspectives, users can only use one of these perspectives during the avatar creation.

2.3 Existing Software Difficulties

Table 1 summarizes the difficulties associated with the software that is used to support the creation of virtual avatars. On this basis, we analyze the problems with existing software for creating virtual avatars.

A common problem in many existing software programs is that they force users who are engaged in the creative activity of designing and creating avatars to adjust the parameters. (i) to embody the ideal avatar that is initially drawn in users' minds, the ideal avatar needs to be converted into several parameters that are convenient for the computer. This mapping of parameters to the avatar shape and size is not easy for novices. (ii) to teach these parameters to the computer, users must perform detailed tasks, such as moving sliders and entering keyboard input. This is tedious for novices. Furthermore, as users repeat steps (i) and (ii), they become absorbed in the "task" of adjusting the parameters and as a result, they may lose the perspective and reasoning of viewing the appearance of the avatars as a whole, or of thinking flexibly and freely.

Another frequent issue in existing software packages is that users cannot experience their own avatars in virtual spaces during the creation process. Similar to the concept of purchasing or making clothing in the real world, users wish to be aware of how their avatar appears to them (first-person perspective) and how it appears to others (third-person perspective) when creating their own avatar. In many existing software programs, users create their avatars only from the third-person perspective, which may result in a large discrepancy between the avatar the user originally wished to create and completed avatar when the completed avatar is viewed from the first-person perspective in virtual spaces. Although Cluster supports both first- and third-person perspectives, it is not possible to switch between the two during the creation process.

Table 1: Software difficulties in supporting virtual avatar creation.

Type	Difficulties
3D modeling software	• Knowledge of 3D modeling is required • Complex operation • Difficult to imagine the shape, thickness, and size of the 3D avatar on a 2D display, and ultimately, how the avatar will be represented in virtual spaces
Avatar creation software for desktop PCs	• Many parameters to adjust • Difficult to map the parameters to the avatar geometry • Difficult to imagine the shape, thickness, and size of the 3D avatar on a 2D display, and ultimately, how the avatar will be represented in virtual spaces
Avatar creation software for smartphones	• Fat finger problem • Difficult to imagine the shape, thickness, and size of the 3D avatar on a 2D display, and ultimately, how the avatar will be represented in virtual spaces
Avatar creation capabilities on social VR platforms	• The same interface as smartphone avatar creation software; may not be optimal for avatar creation in 3D space • Users can only use either the third- or first-person perspective during avatar creation

3 SYSTEM CONCEPTS

Table 2 displays the system concepts that are derived from the analysis of problems with existing software for virtual-avatar creation in the previous section.

Concept (1), namely gesture-based direct manipulation of life-size avatars, is derived from the problem in the second paragraph of Section 2.3. Users should be able to change the body, hair, and clothes of a life-size avatar by directly touching with their hands, rather than by setting parameters, to enable them to embody the ideal avatar in their minds intuitively.

Concept (2), namely switchable perspectives (first-person or third-person), is derived from the problem in the final paragraph of Section 2.3. Users should be able to create their avatars in virtual spaces from both perspectives (first- and third-person) to enable them to create their avatars while determining the appearance of the avatars in the virtual space, that is, how they appear from the users' and others' perspectives.

Table 2: System concepts for supporting virtual-avatar creation for novices.

(1) Gesture-based direct manipulation of life-size avatars
(2) Switchable perspectives (first-person or third-person)

4 INTERACTION DESIGN

We designed interactions that satisfy the system concepts listed in Table 2. Figure 6 depicts a usage scenario of the proposed system.

4.1 Gesture-Based Direct Manipulation of Life-Size Avatars

To satisfy Concept (1) in Table 2, users of this system, such as general users in the virtual space, are represented as full-body self-avatars and they create avatars for themselves. Users can directly change their own body, hair, and clothes through gestures such as "pulling," "pushing in," "lifting," "stretching," and "depressing". Parts 1 to 8 in Figure 2 indicate the manipulable parts, which are enclosed by red dashed lines and can be directly manipulated by users with gestures in our system. Users can change the shape of their own (avatar's) body, hair, and clothes by moving the guide object that is represented by a blue wedge next to the manipulable part in Figure 2.

The interaction for changing the shape of the manipulable part, using the sleeve fullness (Figure 2, 1) as an example, is described in the following. When a user wishes to change the degree of sleeve fullness, they first select one of the multiple blue wedge-shaped guide objects [Figure 3(c)] that are placed along the avatar's forearm, at the point they wish to change. Subsequently, they pinch one of the guide objects and only the guide object turns red [Figure 3(a)]. If the user lifts the red guide object, the degree of fullness of the manipulable part [Figure 3(b)] that is associated with the red object, changes. Guide objects can also be hidden if the user wishes to view their avatar's appearance. Table 3 summarizes the interactions when changing each manipulable part (Figure 2, 1 to 8).

4.2 Perspective Switching

To satisfy Concept (2) in Table 2, our system supports both first- and third-person perspectives, thereby allowing the users to switch between the two perspectives in virtual spaces (Figure 5).

In the first-person perspective mode (Figure 5, left), the users are represented as full-body self-avatars in virtual spaces. The target avatar for creation is themselves (i.e., a self-avatar). The users touch their own (self-avatar's) manipulable parts with their

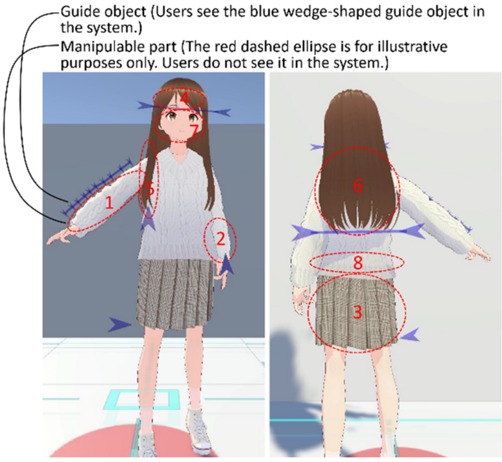

Figure 2: Manipulable parts (red dashed ellipses) and guide objects (blue wedges) for body, hair, and clothing. Users can change the shapes of the manipulable parts by moving the corresponding guide objects.

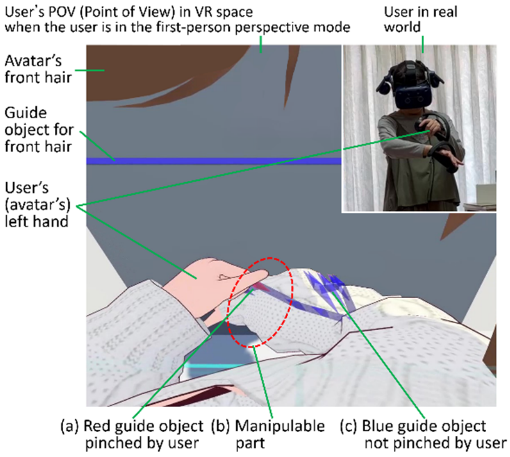

Figure 3: User's perspective when looking down at their (avatar's) right arm and changing the degree of sleeve fullness of that arm with their (avatar's) left hand..

Table 3: Gesture-based direct manipulation of life-size avatar for changing body, hair, and clothes.

Manipulable part (Figure 5)		User action (before)	System feedback (after)	Illustration
Clothes	Sleeve fullness (1)	Pinch the part of the sleeve to be inflated and pull/push it in	Sleeve bulges/dents	Figure 6
	Sleeve length (2)	Pinch the cuff and pull/push it in	Sleeve lengthens/shortens	Figure 7, upper left
	Skirt length (3)	Grasp the edge of the skirt and pull it up/down	Skirt lengthens/shortens	Figure 7, upper center
	Skirt spread (3)	Grasp the edge of the skirt and spread/narrow it	Skirt widens/shrinks	
Hair	Front hair length (4)	Pinch the end of the front hair and pull it up/down	Front hair lengthens/shortens	Figure 7, upper right
	Direction and parting of front hair (4)	Hold the front hair and move it from side to side	Direction and parting of front hair changes	
	Side hair length (5)	Pinch the end of the side hair and pull it up/down	Side hair lengthens/shortens	
	Back hair length (6)	Pinch the end of the back hair and pull it up/down	Back hair lengthens/shortens	
Body and face	Face shape/cheek fullness (7)	Touch the cheek with the palm of the hand and press it in/expand it	Face shape becomes slimmer/rounded	Figure 7, lower left
	Waist position (8)	Grasp the waist and pull it up/down	Waist rises/lowers	Figure 7, lower center

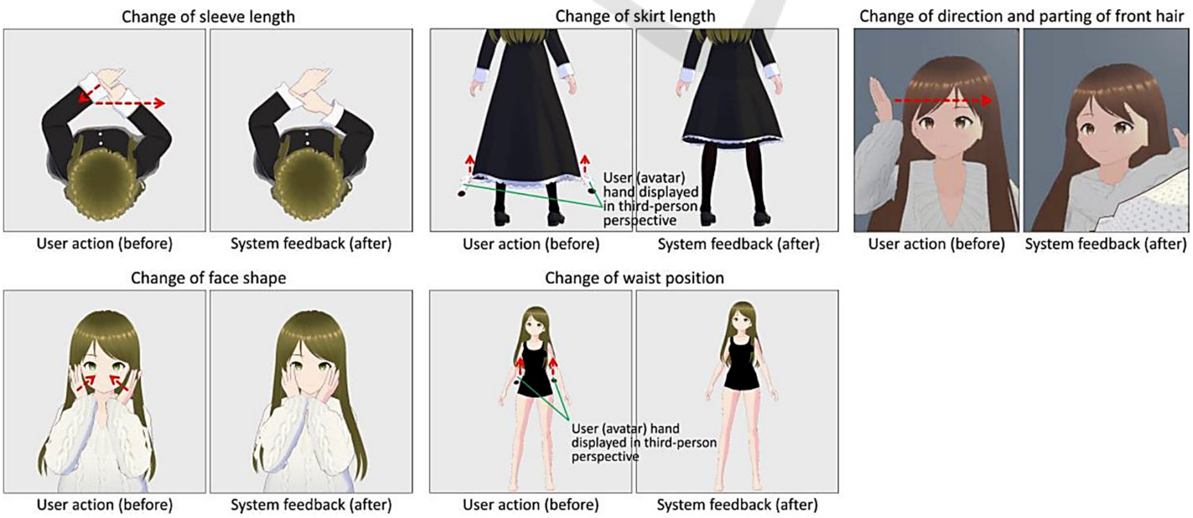

Figure 4: Before and after each manipulation.

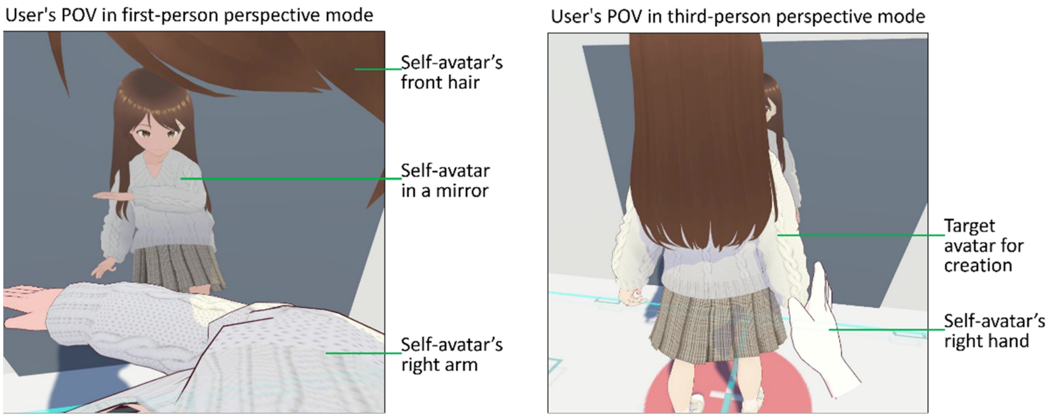

Figure 5: User's perspective in first-person (left) and third-person (right) perspective modes.

own (self-avatar's) hands. As the users cannot view the full-body target avatar (themselves) in the first-person perspective mode, a mirror is placed in front of the self-avatar. Manipulable parts that are suitable for manipulation in the first-person perspective mode include the sleeves, front hair, side hair, face shape, and waist position.

In the third-person perspective mode (Figure 5, right), the users are represented as hand self-avatars in the virtual spaces. The target for creation is a fixed avatar in front of the user. The users touch the manipulable part of the target avatar using their own (self-avatar's) hands. In the third-person perspective mode, the users can view the entire body of the target avatar from the outside. Manipulable parts that are suitable for manipulation in the third-person perspective mode include the skirt, back hair, and waist position.

5 PROTOTYPE

Based on the designed interactions that were outlined in the previous section, we developed a prototype of a virtual avatar creation support system that enables gesture-based direct manipulation of life-size avatars and perspective switching.

5.1 System Configuration

We developed the prototype using the Unity software. As for the hardware, a VIVE Pro Eye was used for the head-mounted display (HMD) and a Valve Index controller was used for the controller. The Steam VR plugin was used to acquire the HMD coordinates, detect the controller input, and manipulate objects. Final IK (Unity Technologies, 2022) was used to reflect the HMD and controller coordinates in the movements of the avatar. VRoid Studio (Pixiv Inc., 2021) was used for the avatar and clothing materials. The software consisted of three primary functions (Figure 7). The manipulable parts-change function is described in the following section.

5.2 Change Function for Manipulable Parts

This function enables users to manipulate the guide object using gestures to change the shape of the manipulable part. First, the system calculates the distance the user moved the guide object. This is the amount of movement based on the initial position set for each manipulable part. Subsequently, the system multiplies this amount of movement by the scalar multiplier set for each manipulable part and applies it to the blendshape of the manipulable part that is being changed.

6 USER STUDY

We conducted a preliminary user study with three participants using our prototype. This study consisted of two tasks: a scenario task and a free task. In the scenario task, the participants were instructed on the operation of the system and subsequently, they performed each function of the system as instructed. In the free task, the participants operated the system freely for 10 minutes. Finally, they completed questionnaires

6.1 Questionnaires

To evaluate the effectiveness of the two proposed system concepts presented in Table 2, we conducted

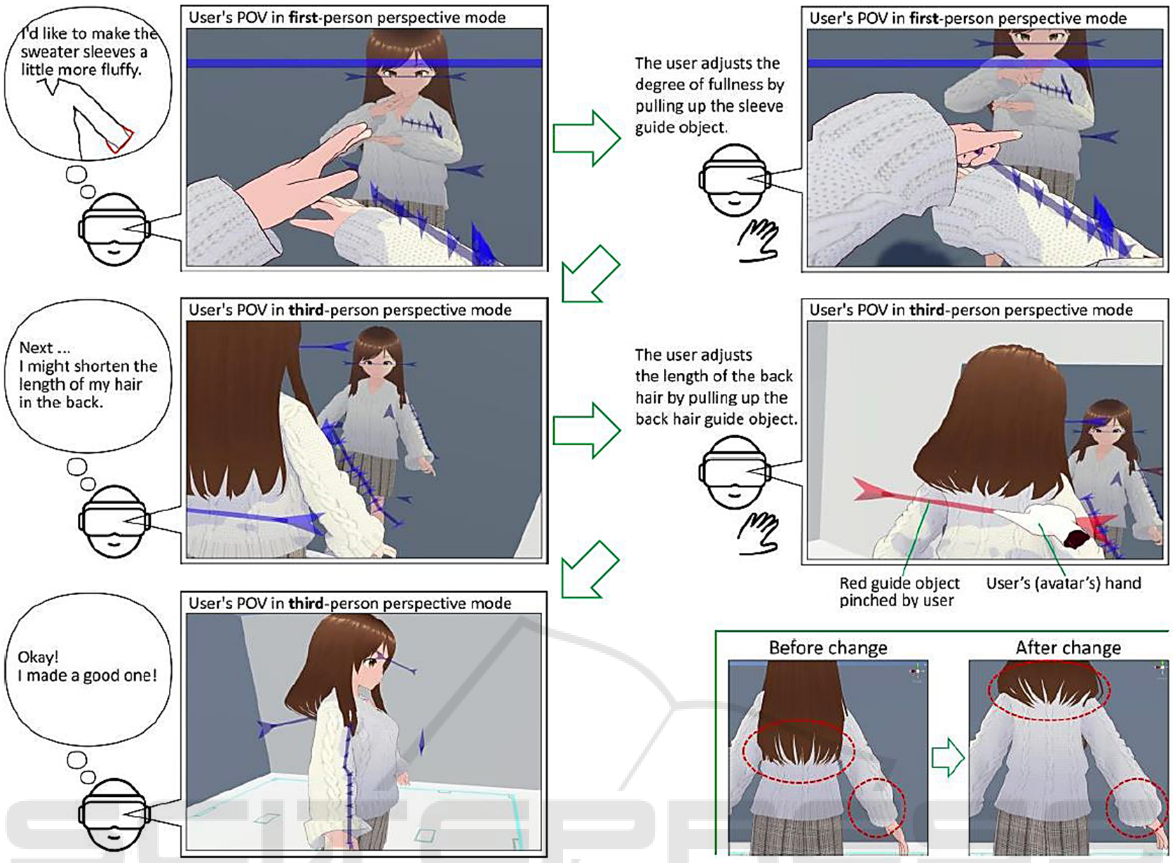

Figure 6: Usage scenario of the proposed system.

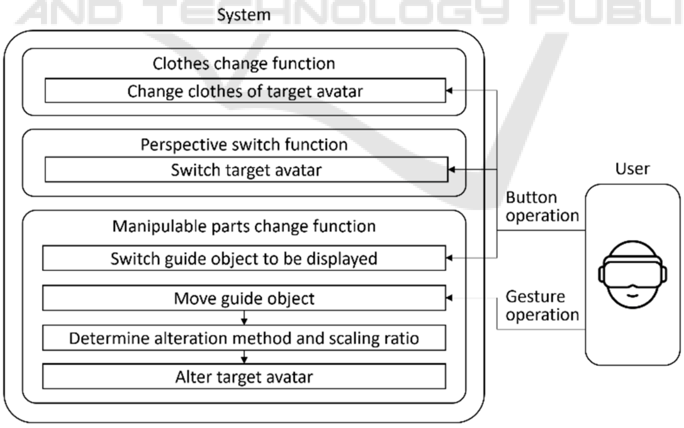

Figure 7: Software configuration.

an open-ended questionnaire and asked the respondents to provide feedback freely, mainly regarding the system concepts.

Moreover, three scales were used to evaluate the general usefulness of the system.

- **Igroup Presence Questionnaire (IPQ):** we used three of the four subscales of the IPQ (General Presence, Spatial Presence, and Involvement) (igroup.org, 2016) to evaluate the presence and involvement of the system. A total of 10 questionnaire items were included using a 7-point Likert scale.
- **System Usability Scale (SUS):** we used the SUS (Usability.gov., 2022) to evaluate the usability of the system. A total of 10 questionnaire items were included using a 5-point Likert scale.

- **Intrinsic Motivation Inventory (IMI):** we used four of the seven subscales of the IMI (Interest/Enjoyment, Perceived Competence, Effectiveness/Importance, and Value/Usefulness) (Self-Determination Theory, 2022) to evaluate the intrinsic motivation of the system. A total of 25 questionnaire items were included using a 7-point Likert scale.

6.2 Results and Discussion

6.2.1 Effectiveness of System Concepts

Positive comments relating to our system concepts included the following:

- *"It was exciting to touch my own body (in first-person perspective mode) while creating the avatar, and it was also interesting to see and touch myself from the outside (in third-person perspective mode).*
- *"I liked the fact that I could see how my avatar would actually look in virtual spaces when I was creating it."*
- *"I think it's good that I can customize my avatar with intuitive operations, and that I can switch perspectives."*
- *"It was great to be able to adjust the subtle length of the hair on the front and sides while looking in the mirror (from a first-person perspective). It was also nice to be able to adjust the length of the back hair by looking at it from behind (from a third-person perspective). It would be interesting to be able to change not only the length and parting of the hair, but also the degree of wave of the hair."*

These comments suggest that the participants evaluated the two system concepts. In particular, they noted that the proposed system would be useful for adjusting parts that are more difficult to specify using parameters, such as the hair parting and sleeve fullness.

However, several negative comments regarding the system concept were provided:

- *"It was difficult to understand the range of each changeable arrow (guide object) on the sleeves, and it became a mess."*
- *"In this system, we touch wedges (guide objects) to change the shape of clothes and the length of hair, but I thought it would be better if we could touch clothes and hair (directly) instead of wedges, just as we usually touch them."*

These comments suggest that substantial room for improvement exists in the guide objects that are used to manipulate the manipulable parts. It may be possible to increase the "resolution" of the guide objects (i.e., reduce the changeable range of a single guide object and locate the guide objects more densely). If the resolution of the guide objects is sufficiently high, users will be able to change the shape of the sleeve as if they are "touching the cloth directly," without being aware of the guide objects. In this case, it would be better to use a hand-tracking function instead of the controller of the current system to recognize detailed movements of the user's fingertips.

Furthermore, all the participants requested the ability to customize various parts further. In addition to the manipulable parts demonstrated in this study (Figure 2, Table 3), it is possible to expand the design elements that are difficult to set with parameters, such as the degree of the hair wave mentioned by one of the participants.

6.2.2 General Usefulness of System

The results of the ratings of the participants for each subscale of each scale (IPQ, SUS, and IMI) are presented in Table 6. Although there were only three participants, their ratings of the IPQ, SUS, and IMI scales were high, suggesting the usefulness of our system. Overall, the evaluation score of P3 was lower than that of the other participants. This may be owed to the fact that P3 was the only participant who had no experience using VR systems.

Table 6: Results of participant ratings.

Scale	Subscale	Full points	P1	P2	P3	Mean
IPQ	General Presence	6	6.00	6.00	6.00	6.00
	Spatial Presence	6	4.40	4.40	4.80	4.53
	Involvement	6	4.75	5.75	5.25	5.25
SUS		100	95.0	90.0	62.5	82.5
IMI	Interest/Enjoyment	7	6.71	7.00	6.43	6.71
	Perceived Competence	7	5.83	7.00	3.67	5.50
	Effort/Importance	7	6.80	7.00	6.80	6.87
	Value/Usefulness	7	6.86	7.00	6.71	6.86

7 CONCLUSION

We have proposed a system that supports the activity of creating virtual avatars for novices using embodied interaction. First, we analyzed the problems with existing software for the creation of virtual avatars. Based on these problems, we derived two system concepts: gesture-based direct manipulation of life-size avatars and perspective switching. Subsequently, we designed an interaction to satisfy these two concepts and developed a prototype. In the first-person perspective mode, users are represented as full-body self-avatars in virtual spaces, and they create their avatars in manners such as by changing the length of the self-avatar's sleeves through pulling on the self-avatar's hand or changing the parting of the self-avatar's front hair in the mirror by touching the self-avatar's hand. In the third-person mode, users are represented as hand self-avatars in front of the target avatar for creation in virtual spaces, and they create their avatars in manners such as by changing the length of the target avatar's back hair with the hand self-avatar from behind or changing the length of the target avatar's skirt with the hand self-avatar. We conducted a preliminary user study with three participants using the prototype. The results suggest that these two system concepts were generally positively accepted. In particular, we determined that the proposed system is useful for adjusting parts that are more difficult to specify using parameters, such as the parting of hair and fullness of sleeves.

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