Live Emoji: Semantic Emotional Expressiveness of 2D Live Animation

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ABSTRACT
Live animation of 2D characters has recently become a popular way for storytelling, and has potential application scenarios like tele-present agents or robots. As an extension of human-human communication, there is a need for augmenting the emotional communication experience of live animation. In this paper, we explore the emotional expressiveness issue of 2D live animation. In particular, we propose a descriptive emotion command model to bind a triggering action, the semantic meaning, psychology measurements, and behaviors of an emotional expression. Based on the model, we designed and implemented a proof-of-concept 2D live animation system, where a novel visual programming tool for editing the behaviors of 2D digital characters, and an emotion command recommendation algorithm are proposed. Through a user evaluation, we showcase the usability of our system and its potential for boosting creativity and enhancing the emotional communication experience.

CCS CONCEPTS
• Human-centered computing → Interactive systems and tools;

KEYWORDS
Live animation; Emoji; Visual programming; Affective computing.

1 INTRODUCTION
Live animation, as a new form of storytelling, opens the possibility of online communication through controlling a digital character. For example, through the usage of Adobe Character Animator [1], users can manipulate the behaviors of a puppet in real-time during online chatting. As previous research works show that emotional expressiveness can bring more engaged experience to audiences [2, 19], equipping 2D live animation with emotional tools can potentially fulfill online communication tasks, e.g., news broadcasting, interacting with students or children remotely, etc., better.

However, expressing emotional states of 2D live animation is challenging [13, 19, 22]. Generally, facial expressions of digital puppets are the most salient channel for expressing emotions [19]. Existing approaches, such as expression transfer [6] and swapping artworks [22], are still difficult or not easy for users to communicate full range emotional states reliably. For expression transfer, namely, capturing users’ facial expressions and deforming the digital puppet accordingly, it is difficult for users to express different deliberate emotions. For swapping artworks that changes different puppet faces according to different emotional states, it is also challenging to design artworks with different emotions that can be recognized reliably, especially for subtle emotions [13]. In addition, users might need to customize emotions to express specific semantic meanings [25]. The basic categories of emotions [18], i.e., happy, sad, fearful, angry, surprised, disgusted, are not enough to express secondary emotions or emotional experiences in different contexts precisely [26]. For instance, the emotional state of a person riding a roller coaster is hard to be classified into any one category. To express secondary emotions, dimensional emotion models are needed, such as the circumplex model [14], the Geneva emotion model [18], and so on, which describe the geometric emotion space under two or more channels [26]. However, designing different puppet faces with different secondary emotions and swapping them during live animation is still a challenging task, and even not possible if the story is not planned beforehand, i.e., no prior contextual information.

The diverse emoji and sticks in current online communication tools provide a novel perspective to deal with the emotional expressiveness problem in live animation. With the usage of emoji and stickers, senders can express the emotion feeling of a text message better, and receivers can also feel the sentiment of the message more saliently. Popular chatting softwares, e.g., Wechat 1, QQ 2, and so on, build in powerful emoji functions to provide a rich emotional chatting experience, which is very welcomed by users [28]. Specifically, stickers exaggerate the traditional emoji, and are extremely popular among the younger generation in China [28]. Compared to traditional emojis, stickers are usually created by modifying real photos, cartoons, with exaggerated facial expressions, background animated texture patterns, and illustrated texts to enhance emotion feeling.

1 weixin.qq.com
2 im.qq.com
Using emotional expressing ways of stickers can potentially enhance the emotional expressiveness ability of live animation, which leads to better storytelling and communication experience. In this paper, we explore how to help users make rich emoji with expected semantic meanings, e.g., happy, sad, etc., and control customized emoji in real-time through live animation. In particular, we designed and implemented an easy-to-use 2D live animation system to help users express emotional states more efficiently. To represent diverse secondary emotions, following the results of Sonderegger et al. [19], we used a dimensional emotional model, and decomposed the emotional state into valence and arousal levels. We collected a dataset of popular stickers, and identified three main components for expressing emotional meanings, i.e., facial expressions, background texture patterns, and texts. Finally, we built a visual programming tool that allows users to combine different elements of the three components to create a rich emoji easily and intuitively.

To conceptualize the emotional expressiveness during live animation, we propose an emotion command model that binds a triggering action, the semantic meaning of an emotion, psychology measurement metrics [18], and the behaviors of a digital puppet together. The model makes it convenient for users to connect different expected semantic meanings with a particular puppet’s behaviors during live animation, and also helps simplify the design of our live animation system. In addition, with the bound psychology measurements, we can also build recommendation algorithms to recommend particular emotion commands during live animation. Through a preliminary user evaluation, we show that our system can help users build interesting emoji, and express emotional states easily during live animation. The contributions of this paper can be summarized as:

1. Building on the dimensional emotion model, we propose an emotion command model to conceptualize emotional expressiveness of live animation. In addition, leveraging the procedural animation concept, we designed and implemented a visual programming tool to edit an emotion command.
2. Targeting online communication scenarios, we designed and implemented a proof-of-concept 2D live animation system.
3. We conducted a preliminary user evaluation to explore the usability of our system.

## 2 RELATED WORKS

### Live Animation

Controlling a puppet to tell stories has been a long time theatrical practice. Previous works of digitalizing live animation include simulating Chinese shadow puppetry [12], controlling marionettes in a Virtual Reality (VR) environment [16], and so on. The recent development of face tracking techniques brings new design forms of digital live animation tools, e.g., the software Adobe Character Animator. In [22], researchers propose a recommendation triggering strategy using touch screens, which significantly decreases the perceptual workload during live animation. In [21], by the usage of physical simulation, researchers add secondary motion to a primary motion to make more lively visual effects.

Previous works usually focus on how to align the motion trajectories of performers and the puppets, but how to augment the movements of performers to express rich emotional states correctly is more challenging. The introduction of secondary motion [21] provides promising results in this direction. However it is still problematic for users to express different secondary emotions mentioned previously.

### Emotional Representation

Emotional experience is important for better social communication [7], and plays an important role in human-human interaction, human-robot interaction, and human-computer interaction. Allowing an agent to express diverse emotional states could engage its users better, and has attracted many research efforts recently.

For emotional representation, one crucial question is how to define emotion itself. In general, there are three different points of view, i.e., discrete categories, e.g., Ekman’s six basic emotions [8], the dimensional model, e.g., the circumplex model [14], and the appraisal-based model, e.g., the Geneva emotion model [18], which can be seen as an extension of dimensional models. Discrete categories are shown to be cross-cultural, and easy for humans to recognize, but suffer from describing secondary emotions. Therefore, to represent diverse emotional states, dimensional models are expected. Another problem is which communication channel should be used to convey emotions. Works on displaying emotions include different sensory channels, for instance, temperature [20, 24], color [3], embodied emotional feedback [9], vibration [5], visualization and animation [19], and the fusion of multiple signals [23], and so on.

Inspired by the popularity of stickers [28], our work explores representing emotions by dimensional models through facial expressions, animation of background texture patterns, and explicit illustration with texts. In addition, to enable users to express diverse semantic meanings of emotional states during live animation, an easy-to-use tool for composing different emoji is needed.

### Visual Programming

As suggested in [17], using programming tools can help create more complex animation effects. However, programming is usually a challenging task for non-professionals [17]. Researchers have explored different approaches to facilitate
this procedure, e.g., direct manipulation on graphics [11, 17], visual programming tools, etc. For example, in [11], Draco is proposed, which allows users to program the expected motion trajectories by drawing. Similarly, a physical illustration tool in [17] allows users to program the relationships of different objects by connecting them with a mouse.

Using visual programming tools is another alternative to make programming accessible by novices, e.g., the visual programming language Scratch [15]. Among many visual programming tools, the behavior tree model is a simplified version for editing behaviors of digital characters, which is widely used in the game industry. However, the general design of a behavior tree model is still not flexible enough for the context of emotional expressiveness of live animation. And for novices, picking up concepts in behavior tree models is also challenging. More care should be taken to tailor a suitable behavior tree model for the usage of emotional expressiveness of live animation.

The remaining of the paper is organized as follows. We first present the proposed emotion command model. And then we introduce the interface design of our live animation system, following the implementation details, including a visualization tool, a visual programming tool, the default live animation function, and a recommendation algorithm. In the following, we present the initial use case study and result analysis. Finally, we discuss the limitations of this work and potential further directions.

3 EMOTION COMMAND MODEL

To conceptualize emotional expressiveness of 2D live animation, we propose an emotion command model. An emotion command combines a triggering action, the semantic meaning of an emotion, different measurement metrics, e.g., valence, arousal, etc., and the animated behaviors together. By triggering an emotion command, a particular emotional behavior can be presented. The conceptualization of emotional expressiveness helps simplify the system design procedure. In addition, we can also help users build their customized emotional communication vocabulary. Finally, with the model, it is also manipulatable to design algorithms for recommending the expected emotion commands during live animation.

An emotion command can be represented as a five element tuple:

\[(d, s, v, a, b),\]

where \(d \in D\) is a triggering action of a particular device (keyboard in this paper), \(s \in S\) is the semantic meaning of the emotion command given by users, \(v \in \mathbb{R}\) and \(a \in \mathbb{R}\) are the valence (happiness) level and arousal (activation) level reported by users respectively, \(b \in B\) is the behavior actions of the puppet triggered by \(d\).

To construct \(b\) with diverse expressiveness using basic components, we collected 216 stickers from QQ and Wechat. In particular, we used the emic approach [10], and treated ourselves as participants in several chatting groups and peer-to-peer chatting processes. We collected stickers that can express a strong emotional feeling during chatting. Some stickers are animated while some are not. Several examples of the dataset are shown in Table 1. To code the dataset, the authors had regular meetings and discussions, and finally identified three main components for conveying rich emotional feeling: facial expression \(F\), background texture pattern \(T\), and text \(O\). Therefore, a behavior action is a tuple: \(b = (f^*, t^*, o^*)\), where * denotes \(b\) can contain zero, one, or more sub-action \(f, t, o, f \in F, t \in T, \) and \(o \in O\).

| Table 1: Several examples of our collected emotional sticker dataset. |

4 USER INTERFACE

We designed and implemented a proof-of-concept 2D live animation system Live Emoji to demonstrate the emotion command model. The general workflow of our system is that users first edit a corpus of emotion commands through a visual programming tool, connect to a remote partner, control a telepresence puppet through live animation, and then trigger emotion commands to enhance the emotional communication experience.

We denote the two partners communicating with each other as performer and audience, where the performer is the side that users control the puppet and trigger the emotion commands, and the audience is the side that users watch and interact with a telepresence puppet.

The interface of the performer side is shown in Figure 1, which contains the main canvas (A) for displaying the animated puppet, the emotion command view (B) for collecting all the emotion commands edited by users, the mode view (C) for choosing different usage mode, i.e., the layout of the interface (audience, performer), usage stage (live animation, editing emotion commands), and character selection (boy, girl), the emotion view (D) for visualizing the valence and
arousal levels for helping users edit the emotion command, the menu bar (E) for other helpful functions, e.g., toggling the performer view (F) that displays users themselves, the audience view (G) that displays the remote partner, the visual programming view (Figure 2) to edit emotion commands, changing the background image, and so on.

The audience side only contains the main canvas (A), the optional audience view (F) for displaying the remote partner, and the menu bar (E).

Workflow

Editing Emotion Command. To edit an emotion command \((d, s, v, a, b)\), users need to input the bound key \(d\) and the semantic meaning \(s\), e.g., happy, sad, etc. The emotion view (D) provides a visualization tool to assist users to self-evaluate the valence level \(v\) and arousal level \(a\) of the expected semantic meaning. The visual programming tool allows users to visually edit multiple behaviors \(b\) shown in the main canvas (A), including facial expressions, background texture patterns, and texts.

Live Animation. During live animation, we built in a default live animation function, where the system detects users’ facial information for controlling basic states of the digital puppet, e.g., open or close eyes, face position, etc. Users can trigger an emotion command by pressing the key \(d\) to display the animated behaviors \(b\). In addition, with a corpus of emotion commands pre-edited by users, the system can estimate users’ valence and arousal levels during live animation, and recommend several emotion commands.

5 SYSTEM IMPLEMENTATION

We implemented the system using Javascript. The scene graph is organized with Threejs \(^3\). Apart from face tracking, for other face related algorithms, i.e., facial expression recognition, eye blink detection, face landmark detection, mouth open or closed detection, we adopted existing libraries through a trial and error procedure. The communication between two partners was implemented with the technology WebRTC webrtc.org, and our system can be used with an ordinary network setting.

Character Representation

To simplify the system, we only provide pre-set characters with head portraits. Two professional artists were invited to help us design the characters, including a boy character and a girl character, as shown in Table 2. The face portrait of each character is discretized as:

\[
\Gamma = \{\text{static}, \text{eye}_i^L, \text{eye}_i^R, \text{eyebrow}_i^L, \text{eyebrow}_i^R, \text{mouth}_i, \text{nose}_i\},
\]

where static denotes static decorative parts that are not changed during live animation, including left and right ears, front face, and hair, \(L\) denotes left, \(R\) denotes right, \(i\) is the emotional state, and

\[i \in \{\text{happy, sad, fearful, angry, surprised, disgusted}\}.\]

Table 2: The designed characters (1st row: boy, 2nd row: girl) used in Live Emoji. From left to right, the expressions are: neutral, happy, sad, angry, fearful, surprised, disgusted.

The controllable parameters of \(\Gamma\) are \((x, y, i, \xi^l, \xi^r, \xi)\), where \(x\) and \(y\) are the horizontal and vertical positions, \(i\) is the emotion state, \(\xi^l\) indicates the close state of left eye, i.e., if \(\xi^l = 1\), left eye is closed, similarly, \(\xi^r\) is the close state of right eye, \(\xi\) is the open state of mouth, and if \(\xi = 1\), mouth is open. During live animation, the system estimated the state of users to control \(x, y, \xi^l, \xi^r, \xi\) automatically, and \(i\) is triggered by emotion commands to change different emotion artworks of the character.

\(^3\)https://threejs.org
To enable the reliable recognition of different facial expressions, we adopted the guidelines in [13] for designing facial features of six basic emotions. Although the six emotions are not enough for users to describe various secondary emotional states, for facial expressions except the six basic ones, it is usually hard to be recognized reliably [13]. Therefore, it might be confusing for users to choose different facial expressions. In addition, according to the circumplex model [14], the six basic emotions can cover most parts of the geometric distribution uniformly, which means any emotions including the secondary emotions mentioned previously can be approximated by one of the six emotions. Referring to the use of practice of emoji, our design consideration is to rely on the combination of the three different channels, i.e., facial expression, background animation, and text, to express subtle emotions. The feedback from users also indicates the approach is meaningful. In addition, we found that the way of speaking emotion meanings straightforward with animated texts is especially useful.

**Visualization Tool for Emotion Evaluation**

To edit an emotion command, users need to evaluate the valence and arousal value of the semantic emotion meaning, which are used for building the recommendation algorithm. We designed a visualization tool to assist users to self report the expected values, as shown in Table 3. For both panels, users can drag the slider to change the values, and the corresponding visualization and numerical results are updated. A professional artist was invited to draw the facial expressions of different valence levels referring to the 9 scale Self-Assessment-Manikin (SAM) [4] (1-9, 5 by default). Inspired by [19], where animated background can convey different levels of arousal meaning better, we used an animated heart to indicate different arousal levels. The numerical range is set to be 50 ~ 90 (70 by default) to reflect the common sense of normal heart rate, where higher heart rate indicates higher arousal level, and lower heart rate indicates lower arousal level.

| Valence | Arousal |
|---------|---------|
| ![Valence](image1.png) | ![Arousal](image2.png) |

Table 3: The visualization tools for self reporting valence (left) and arousal (right) level.

**Visual Programming Tool for Behavior Editing**

We modified a standard behavior tree model (BT) for building the visual programming tool, which provides users an easy-to-use tool for composing an emotion command.

A behavior tree model is a directed acyclic graph $G(V, E)$ with $|V|$ nodes and $|E|$ edges. The child-less nodes are called leaf, and the parent-less nodes are called root. Each node in a BT, is one of seven possible types: root, four non-leaf control-flow node types, i.e., selector, sequence, parallel, and decorator, and two leaf execution node types, i.e., action, and condition. For a digital puppet, a shot of behaviors can be composed by one root node, with several control-flow nodes, and several execution nodes, with the structure:

$$\text{root} \rightarrow \text{control} \rightarrow \text{execution},$$

The root node is to indicate the target puppet, the control node is to control the logic of the behaviors, and the execution node is the real actions of the digital puppet. In addition, users can concatenate several shots of behavior together to compose more complicated behavior actions.

Although behavior tree is widely used in game industry, enabling novices to pick up the aforementioned concepts is still difficult. We modified several definition rules to better fit our emotional state manipulation task and make it intuitive for novices.

**Design Rationale.** With the emotion command model and our emoji dataset, we designed the modified behavior tree with the following rationales:

1. Users should have the flexibility to add any combination of the three basic components, i.e., facial expression, background animation, and text, which are commonly seen in online chatting emoji.
2. Users can bind any number of the behavior actions to a particular component.
3. Some actions can be used only for specific components, e.g., the face swapping action for the face component. However, to give users more degree of freedom to connect component nodes and action nodes and simplify the behavior tree model, it is desirable to abstract several common behavior actions of the three different components, e.g., vibration.

**Modified Behavior Tree.** To meet the design requirements, we included only three types of nodes in our modified behavior tree model, root+, sequence+, and action. The visual programming tool of an emotion command has the following structure:

$$\text{root}+ \rightarrow \text{sequence}+ \rightarrow \text{action}.$$ 

The interface of the visual programming tool is shown in Figure 2, which includes a navigation bar (A) for adding different nodes (root+, sequence+, action) and editing the command (e.g., new, save, import, export), and the main canvas (B) for visual programming the emotion command. Root+ node is a parametric node for binding the semantic
meaning $s$, valence $v$, arousal $a$, and key $d$. One sequence+ node corresponds to a target component, i.e., facial expression, background animation, text, and it is used to connect different action nodes for that component. The behaviors $b$ are composed by sequence+ and action nodes together. The connection between the root+ node to the sequence+ node allows users to compose an emoji by selecting any combination of the components, and the connection between the sequence+ and action node provides the flexibility to decorate various behaviors of a component.

**Action Node.** We designed five different action nodes for the proof-of-concept system, but with the general emotion command model, it is easy to add additional behavior actions.

**Danmaku Action.** The danmaku action is inspired by the text comment animation behavior on online video websites, and it is only used for text component. Users can choose to edit the text, font size, color, and the animation manner. Similar to danmaku, the animated texts can be moved from right to left or left to right of the screen. We also built in a shift option to add displacement of the text position, which allows users to place several animated texts on the screen. Although the action is simple, we found it is very helpful for expressing emotional meanings straightly through our user evaluation.

**Swap Action.** The swap action node is used for swapping the facial expressions of the digital puppet. Users can choose one from the six basic emotion templates shown in Figure 2.

**Particle Action.** The particle action is used for creating the particle system of the background component. Users can choose the image texture, the emitter point, the motion pattern (jet, exploding, rain), and the speed of each particle.

As shown in Table 4, we invited artists to design several image textures with six basic emotional meanings, and colorized them referring to the affective color design in [3]. Three typical motion patterns from existing cartoon background effects were implemented, as shown in Figure 3. For jet motion, we uniformly emit particles within an angle $\theta$ around the emitting point with initial velocity, and particles are not influenced by other forces during moving. For exploding motion, particles are produced randomly around the emitting point $E$ with initial velocity, and influenced by gravity. For rain motion, we extend two segments with equal length around the emitting point horizontally, and emit particle randomly along the segments with zero initial velocity, and the particles are influenced by gravity. For all three motion patterns, we gradually make the particle appearance transparent, and add small noises on the initial velocity to make more diverse effects. Again, it is easy to add more texture images and motion patterns for augmenting the current functionality.

**Vibration Action.** To demonstrate the concept that we can abstract common actions of the three components, we
designed a vibration action node that uses one degree-of-freedom vibration behavior for expressing emotions. The vibration action can be connected to all the three components. When a vibration node is triggered, its corresponding component will shake around its position. We allow users to select different levels of frequency and amplitude. The interpolation between endpoints is done by tween.js.

**Sound Action.** We also designed a sound action node that can be connected to the facial expression component. Several human emotional sounds, e.g., laugh, scream, etc., can be chosen in this node. The sound effect files were downloaded from Free Sound Effects.

**Background Image.** Apart from the five action nodes, users can also change the background image that presents different stages for the puppet. Several images from Graphic Mama were downloaded for usage during the evaluation session.

**Default Live Animation**

To provide a live communication experience with the puppet, we bound the controllable parameters $x$, $y$, $\xi_1$, $\xi_2$, $\xi_3$ to the detected states of users by default. When toggling the live animation function, these states of the puppet will follow the detected ones of users. For eye, mouth open / closed detection, and the face position tracking, we used a face landmark detection library clmtrackr to locate users’ eyes, mouth, and face. clmtrackr can outputs 71 landmark coordinate positions of the face, and the result was robust enough for our application during testing.

**Open / closed eye detection.** From face landmark detection, we can get the eye regions. We used keras to train a convolution neural network on the CEW blink detection dataset for classifying the open and closed eyes, and imported the trained model into our system using keras.js.

**Face Tracking.** To alleviate face position drift and jitter effects, face tracking is necessary. In addition, to limit the computation intensive deep learning based algorithms, i.e., open / closed eye detection, emotion recognition (in the following section), a relatively low refresh rate should be given, and thus the tracking procedure can also alleviate the drift problem of low detection rate. In particular, we designed a particle filter for tracking the face. The dynamics of face position is modeled as:

$$
\begin{align*}
\frac{dx}{dt} &= \epsilon_1 \\
\frac{dy}{dt} &= \epsilon_2 \\
\frac{dT}{dt} &= \epsilon_3,
\end{align*}
$$

where $t$ denotes time, and $\epsilon_1 \sim N(0, \delta^2)$, $\epsilon_2 \sim N(0, \delta^2)$ are two different Gaussian random variables. The hidden variable is $h = [x, y, dx/dt, dy/dt]^T$, and the observable variable is $o = [x, y]^T$. The measurement of the face position $m$ is the average value of all landmark positions $l_i$, $m = \frac{1}{N} \sum_{i=1}^{N} l_i$. We adopted a standard condensation particle filter, and used 500 particles to track the position of the face. After testing different illumination conditions, we were satisfied with the tracking result.

**Emotion Command Recommendation**

Once the corpus of emotion commands becomes big, searching the expected emotion command during live animation could be difficult. Therefore, recommending potential suggestions according to users’ spontaneous emotions is necessary. To build a recommendation algorithm, we need to first estimate the valence $V$ and arousal level $A$ during live animation. However, detecting users’ spontaneous emotional states is still a difficult task. For building the live animation system, we explored an experience-oriented approach, where we manually tuned the detected signals to match the mental values self reported by users. And we got two empirical formulas for estimating the valence and arousal levels separately. Based on our initial user evaluation, users were generally satisfied with the results.

**Valence Estimation.** We adopted a categorized emotion recognition engine to estimate the valence level. And the trained model was imported into our system using keras.js. The emotion recognition engine can return the probabilities of six basic emotions or the neutral emotion $P_i$, where

$$i \in \{\text{happy, sad, fearful, angry, surprised, disgusted}\}.$$

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1. https://github.com/tweenjs/tween.js
2. https://www.freesoundeffects.com/free-sounds/
3. human-sound-effects-10037/180/tot_sold/20/10
4. https://github.com/auduno/clmtrackr
5. https://github.com/keras-team/keras
6. https://graphicmama.com/blog/free-cartoon-backgrounds
7. https://github.com/kern
8. https://parnec.nuaa.edu.cn/xtan/data/ClosedEyeDatabases.html
9. https://github.com/transcralial/keras-js
10. https://github.com/oarriaga/face_classification
To encode the probability to the valence value \( V (V \in [1, 9]) \), we separate emotions of the circumplex model as positive (right semi-circle) and negative (left semi-circle). For the largest detected probability \( P_{\text{max}} = \max(p_i) \), if the corresponding emotion is positive, the valence is calculated as \( V = [P_{\text{max}} \times 4] + 5 \), otherwise, \( V = [P_{\text{max}} \times 4] + 1 \).

**Arousal Estimation.** We used the heart rate to approximate the arousal level, and adopted a low cost solution to measure it. As shown in Figure 4, a pulse sensor \( [12] \) is connected to the laptop through an Arduino nano \( [13] \), and we used the Johnny-Five robotics framework \( [14] \) for processing the measured signal. Beats per minute (BPM) is approximated by counting the frequency of peak values in real-time. During experiments, we found that the measured BMP was not aligned with the mental range of arousal values (50–90) well. Therefore, we correct the arousal level with BPM as \( A = 70 + \gamma(BPM - 60) \), where \( \gamma \) is a scale factor parameter (\( \gamma = 1.05 \)).

**Recommendation Algorithm.** By coupling the two dimensional coordinates, we can get the input emotion feature as \( E = (V, A) \). For the pre-edited \( N \) emotion commands, each consists an emotion measurement \( e_i = (v_i, a_i) \), where \( i = 1, \ldots, N \). Based on the circumplex emotion model \( [18] \), a natural way for measuring the similarity of two emotional states is to calculate their Euclidean distance. However, during experiments, due to the noises of valence and arousal estimations, the un-alignment of self reported valence and arousal with the estimated results during live animation, we found that that users were generally not satisfied with the recommended proposals. We went through several versions of designing the recommendation algorithms, and finally decided to recommend the emotion command according to positive and negative emotions separately:

\[
R3 = \begin{cases} 
\arg \min_{e_m \in \text{EM}^\text{positive}} d(e_m, V, A), & V \geq 5 \\
\arg \min_{e_m \in \text{EM}^\text{negative}} d(e_m, V, A), & V < 5 
\end{cases}
\]

where \( R3 \) is the collection of three recommended emotion commands, \( \arg \min \) is the operator of finding arguments of the top three minimal distances \( d(e_m, V, A) \), \( e_m \) is the \( i \)-th emotion command, \( \text{EM}^\text{positive} \) is the collection of all positive emotion commands, i.e., emotion command with \( v \geq 5 \), and \( \text{EM}^\text{negative} \) is the collection of all negative emotion commands, i.e., emotion command with \( v < 5 \). The distance is calculated as the weighted Euclidean measurement:

\[
d_i = \sqrt{||V - v_i||^2 + \alpha||A - a_i||^2},
\]

where \( || \cdot ||^2 \) is the normalized distance (0 ~ 1), \( \alpha \) is the weight coefficient between the valence and arousal levels. During our testing, we found that the estimated arousal did not change too much to reflect the real arousal value of the expected emotion. Therefore, we use a smaller weight (\( \alpha = 0.5 \)) to discount the influence of arousal for computing the distance.

As shown in Table 5, during live animation, we encode the top three recommended commands with different colors, and place them at the top of the emotion command view (left). In addition, to make it convenient for navigating during communication, the recommended commands are also displayed in the audience view (right).

![Figure 4: The device for measuring heart rate.](image)

![Table 5: The recommendation interface (left), and the top three commands are also shown in the audience view (right).](image)

6 **INITIAL USER EVALUATION**

In this paper, we designed and implemented Live Emoji for concept proof of the proposed emotion command model, which conceptualizes the emotional expressiveness problem of 2D live animation. To further explore the usefulness of the system and collected feedback for improvement, we conducted an initial user evaluation. Instead of formally evaluating the usability of our system or comparing with other approaches, our study only served as an exploration of the emotion command concept and the potential application scenario from a user’s point of view. Therefore, we only consider

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12https://pulsesensor.com
13https://store.arduino.cc/usa/arduino-nano
14johnny-five.io
the evaluation from the performer side. Before conducting the user evaluation, we first went through the functions of our system in a group meeting, and adjusted the corresponding features according to the comments to make the system more user friendly.

Participants
Six participants (P1-P6) took part in our user evaluation. Two participants (P2, P4) are professional graphic illustrators with moderate to good drawing skills, and the remaining have little experience on graphics design and drawing. All participants are frequent users of emoji.

Experiment Setting
We prepared six basic emotion commands with semantic meanings happy, sad, angry, surprised, disgusted, fearful beforehand for introducing the different features designed in the visual programming tool, and also served as a basic emotion command corpus for participants to use during live animation. We adopted a laptop with Intel CPU i7 2.6GHz, 8 GB RAM, Nvidia GeForce 920M GPU as the server to run the live animation system, and also used the same computer as the audience side. A laptop with Intel CPU i7 2.2GHz, 16 GB RAM, Intel Iris Pro GPU was used as the performer side for participants to edit the emotion commands and conducted live animation.

Procedure
An overview of our live animation system was introduced first (about 20 minutes), including how to edit an emotion command, how to use the live animation function, and the main potential usage scenario of the system: telepresence agents / robots. Participants were then told to try and explore the system, and we would elaborate the unclear functionalities they asked during the period (about 10 minutes). Then we asked participants to edit four emotion commands, including the semantic meaning of shy, excited, the feeling of hungry, and one that created by participants themselves. No time limitation was set for this stage. After they finished, we conducted an interview to ask their experience of the usability, good, and bad parts of our system. With the four personal edited emotion commands and the six ones prepared beforehand, participants were asked to use the live animation function to tell a self-chosen story to the audience side 15. Again, no time limitation was set. Finally, we collected the user experience on usability, good, and bad parts of our live animation function through an exit interview.

Results and Discussion
In general, participants found the emotion command editing function easy-to-use, flexible for creating diverse emotion expressions, and the live animation function novel, playful.

Usability. Participants found that the workflow and interface design for editing an emotion command was intuitive, and fluent to create an emotion expression. On average, participants took about 3:39 (minutes:seconds, min 1:13, max 9:17) for editing one emotion command, as shown in Table 6. "I think the emotion command function is very interesting to use, and suitable for novices to pick up the concept. It is also very flexible to construct an emoji with different components. The action nodes provide several options to select different levels of motion, which is also quite good." – P1.

In addition, participants generally reflected that the live animation was interesting to use, and acknowledged that the emotion command feature can enhance the expressiveness of emotions. Participants also confirmed that the recommendation algorithm was useful, but not very accurate. We elaborate the recommendation algorithm more in the application section. "I think the live animation function is good to use. And the emotion command can help me express interesting emotion effects, which is helpful for enhancing the emotional communication. The recommendation panel is also helpful, but it is not very accurate currently." – P2. "If there are too many emotion commands, I will have no idea how to find a proper one during live animation. Recommendation is apparently helpful. It is better if you can make it more accurate." – P3.

Creativity. We asked participants to edit a personal emotion command with meaning defined by themselves to let them freely explore the emotion command tool. Participants found the organized way with the visual programming tool was quite useful for boosting their creativity, especially for people without previous experience of graphics design. Participants were generally satisfied with the basic features supported by our system. In the free-form creation stage, participants authored a range of interesting emotion expressions. Several examples are shown in Figure 5. "It is good to have different components for me to compose an emotion expression. I can

| Shy | Excited | Hungry | Free-form (semantic) |
|-----|---------|--------|----------------------|
| P1  | 2:40    | 1:13   | 1:55                | 2:10 (laugh)    |
| P2  | 6:32    | 1:57   | 3:08                | 3:22 (all blue) |
| P3  | 4:01    | 4:15   | 3:00                | 3:11 (amazing)  |
| P4  | 2:15    | 6:01   | 1:48                | 4:18 (furious)  |
| P5  | 9:17    | 5:06   | 5:33                | 5:19 (I want you)|
| P6  | 3:29    | 2:15   | 2:42                | 2:11 (exhausted) |

Table 6: The cost time of editing an emotion command for each participant (the shortest and longest times are highlighted).

15The audience side has no human partner for interactive communication. For the current evaluation, we only consider using the live animation system from the performer side, and allow users to free explore its functionalities.
construct it like building blocks. The provided danmaku node is really useful for conveying some subtle emotion meanings, especially when the facial expression is not diverse enough."–P5. "With the visual programming tool, the logic is quite clear for me, and thus it is helpful for creating new things. I like the function to change the background image. In this way, I can build more vivid emotion illustration."–P2.

**Applicability.** As mentioned previously, our potential target application scenario is for telepresence agents or telepresence robots with a physical body. We asked participants to use the live animation function with the mindset of the target application scenario, and collected their experience of using it. In general, the feedback is positive. Participants reported that the function was playful and interesting, expressing emotions during live animation is also meaningful. "Binding a key in the keyboard with the semantic meaning defined by myself is convenient to use. With the edited emotion commands, I could use more expressive ways during communication."–P1.

Participants thought the recommendation function was helpful, especially when there were lots of emotion commands. However, in the first trial of building our recommendation algorithm (using only Euclidean distance to measure the similarity), participants were not quite satisfied with the recommendation results. We refined the algorithm with the separation of positive and negative emotions presented in the system section, and manually fine-tuned the parameters of estimating the valence and arousal levels to better align with the mental values self reported in the emotion commands. In addition, we optimized the performance of live animation by pausing the computational intensive emotion recognition algorithm during emotion command triggering. We asked two participants (P2, P3) that were not satisfied with the recommendation function in the previous experiment to retry our live animation feature, and they found the improved version was much better than the previous one. "I find the recommendation becomes accurate, and the live animation is also more fluent than the previous one."–P2. "It is better now. Although I cannot say it is perfect. But separating positive and negative emotions can improve the using experience."–P3.

**Interesting Findings.** During our user evaluation, participants also provided some interesting suggestions to improve our system, which inspires us to conduct further works to improve the system.

**Generating emotion commands.** One participant suggested it could be useful if the system can recognize users’ emotions, and generate an emotion command automatically to serve as an initial template. "If possible, it would be good if the system can recognize my emotion, and generate an emotion command automatically. And then the generated emotion command can serve as a template so that it may better fit my expectation."–P5.

**Combining emotion commands.** Due to the limited number of keyboard devices, the number of executable emotion commands is limited. Participants suggested it is possible to combine several emotion commands to generate a new emotional expression. In addition, in this way, it expands the emotion vocabulary for users. "It would be interesting if I can trigger two emotion commands simultaneously, and the system shows the combined emotion expression. I think, in that way, it can give me more flexibility to represent subtle emotions"–P2.

7 CONCLUSION

In this paper, we explore the emotional expressiveness issue of 2D live animation. In particular, we propose a descriptive emotion command model for binding a triggering action, the semantic meaning, psychology measurements, and behaviors. Based on the model, we design and implement a proof-of-concept 2D live animation system for scenarios like telepresence agents or robots for peer-to-peer communication. Through a preliminary user evaluation, we showcase the usability of our system, and indicate its potential for boosting creativity and enhancing the emotional communication experience. In the further works, we plan to enrich the functionalities through computer vision techniques, and also explore its usage in real world applications.

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