Movement Design of Virtual Aerial Robots with Distinct Affective Labels

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ABSTRACT

As robots are progressively introduced in public spaces, it is crucial to develop systems that move appropriately to convey variable internal state and context responsiveness. In this paper, we present six variations of a virtual robot designed after characters from pop-culture. The motion of each character is examined using movement analysis techniques, and the appropriate features are designed for an aerial robot platform in virtual reality. This work is meant to be a foundation for future user studies that investigates how these robot movements are perceived by humans and if varying context changes that perception.

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Figure 1: The five characters (left to right): Sadness, Joy, Fear, Disgust, Anger. Disney-Pixar©

CCS CONCEPTS

• **Human-centered computing** → **Contextual design**; *Virtual reality*; • **Computing methodologies** → **Cognitive robotics**;

KEYWORDS

Context, Social Robotics, Robot Characters, Robotics Design Methodology

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INTRODUCTION

Variable state recognition of an aerial robot among humans is an important factor determining its success as a social robot. It is vital that these robots not only safely navigate physical spaces but also be aware of the social context in their surroundings. This includes measuring details of the environment that should be used to influence the emotive perception of the robot's motion. Similar to the design methodology used in our prior work where characters from Winnie the Pooh were implemented as distinct robot characters [2], this paper will use Disney's *Inside Out* characters to do the same and assign them with different affective labels. This process is enabled by movement analysis, which is described here. Future work will utilize these designs in contextual user studies.

MOVEMENT INSPIRED DESIGN

The storyline of *Inside Out* is based upon five anthropomorphic creatures embodying distinct emotions. These characters are "Sadness", "Joy", "Fear", "Disgust", and "Anger", as shown in Figure 1. The physical motion of each character was studied through the lens of Laban/Bartenieff Movement Studies [3] from the promotional material of the movie [4]. Six robot designs were created after abstracting characteristics that can be overlaid on our virtual robot. Five of the designs are based on the characters and an additional control design acts as a baseline. The movement observations and short descriptions of how these are mapped onto the virtual robot are described below. Figure 2 shows the final designs.

Joy

Pixar classifies Joy as "lighthearted, optimistic and determined" [4]. It is essentially a cheerful character. It has a yellow aura around her and wide-open eyes, focusing towards the audience. The motion is observed to have the following qualities:

- bouncy movement with large steps,

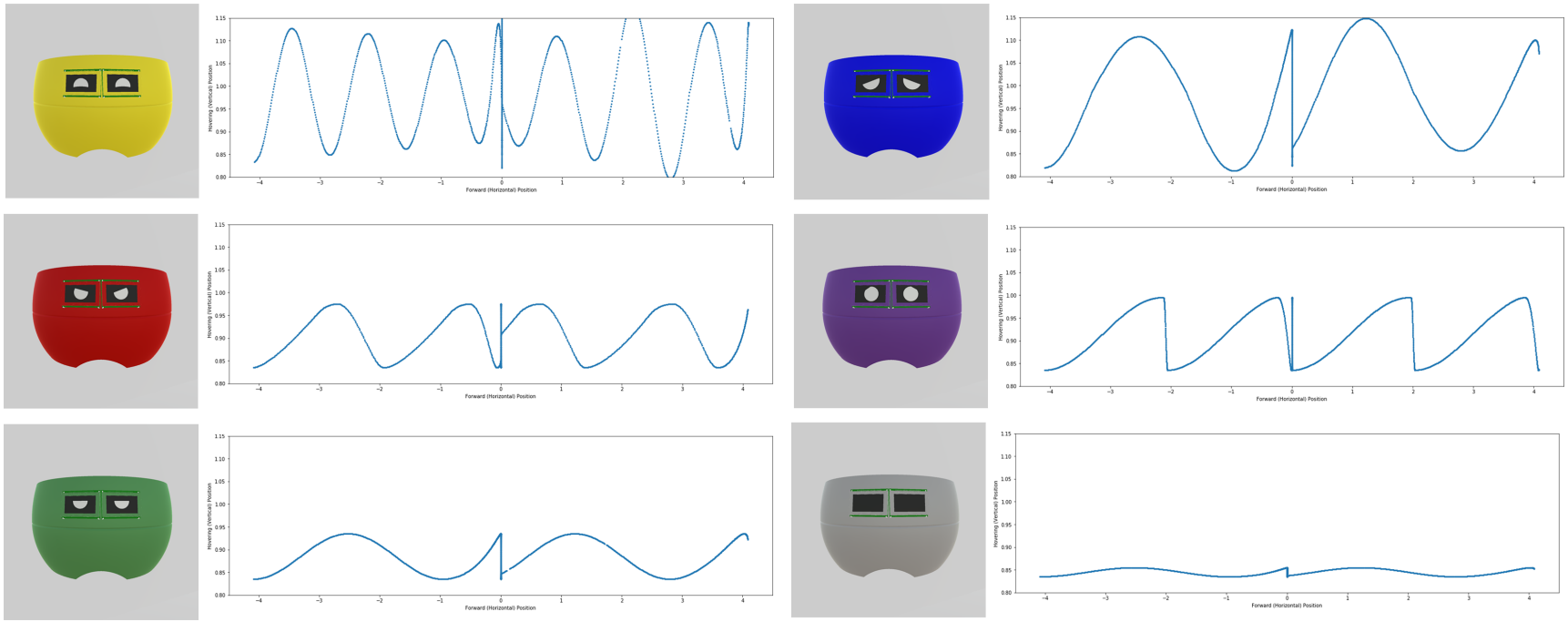

Figure 2: The six robot designs with their motion profiles (clockwise from top left): Joy, Sadness, Fear, Neutral, Disgust, and Anger. The motion profile shows the trajectory of each robot design with the vertical axis showing the vertical position and the horizontal axis showing the horizontal position. The progression of time is from left to right.

- fast motion, and
- head looking up all the time.

The movement is translated to the robot as a sinusoidal wave with a random amplitude at each oscillation to give a bouncy feel. The time period is relatively shorter, which makes the hovering motion quick. A yellowish shade – RBG values: (255, 238, 34) – is assigned to the design.

Robot Design Implementation
CAD software was used to design the shell that was shared by each robot character. The shell was imported to Unity3D, a game development program, where it was given color and different shaped eyes. C#, a programming language, was used to code the character-specific motion for each virtual robot. Several independent variables were used to define the motion of the virtual aerial robot. These are listed below:

- Forward speed
- Upwards Rising speed
- Downwards Falling speed
- Rotational speed
- Amplitude of the vertical movement

Sadness

According to the character description provided by Pixar, Sadness is described to a character who "finds it so hard to be positive" [4]. This is understood by the character's distinct blue color with eyes usually half-closed and looking away from the audience. We analyze the motion as:

- slow and delicate movement,
- dragging of feet, and
- head pointing down.

The slow movement of Sadness is modeled as a sinusoidal wave with a large time period. The slow up and down hover movement gives a dragging effect when the robot moves forward. A randomness factor is added to the amplitude of each oscillation for realism. The design's color is RGB values (0, 0, 255). The eyes are oriented to look down, declining outwards exhibiting droopy eyes.

Anger

Pixar designates Anger to have "a fiery spirit" that is "quick to overreact and has little patience" [4]. It has an aggressive temperament. The character has a red body color along with sharpened eyes. The following motion is observed from Anger:

- strong steps that look like feet stomps,
- raving, erratic movement, and
- sudden infrequent jumps.

A sinusoidal wave with varying time periods is used to ascribe motion to our aerial robot. The stomping motion is implemented by having a quick descend and a slow ascend. The pace of forward movement is independently altered by a sin wave. This change in pace provides a hint of uncertainty in our design. We color our design to the tone of red using RGB values (200, 0, 0). The eyes are designed to be a major segment of a circle pointed upwards.

Fear

Fear is represented by Pixar to be "constantly on the lookout for potential disasters" [4]. It is a cautious character that spends time evaluating each decision pessimistically. The character has a purplish tone with large round eyes. The motion can be characterized as follows:

- combination of fast and slow motion,
- sudden stops, and
- cautious of surrounding.

The vertical motion of Fear is a sinusoidal wave with varying time periods. When the motion is descending, the forward speed of Fear almost comes to a stop. The descending motion happens much

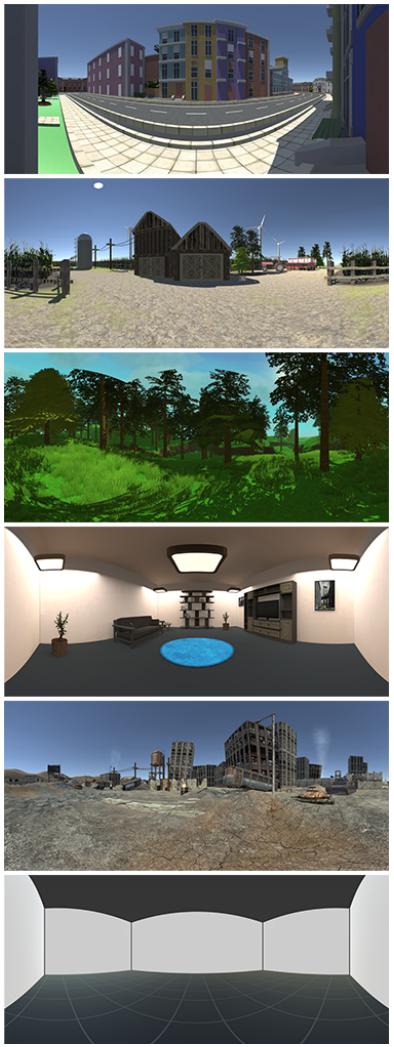

Figure 3: The six environments (top to bottom): Control, Urban, Rural, Nature, Destruction, and Room.

quicker than the ascending motion. The forward speed comes back to normal when the robot is ascending. The whole routine has a comparatively smaller amplitude. The purplish color is represented by RGB value (102, 51, 153). The eyes are designed to be full circles with small notches on the top.

Disgust

Disgust is described by Pixar to be "highly opinionated" and "extremely honest" [4]. At times the character displays indifference. Its purplish color and almost static uninterested eyes are defining characteristics. Disgust has the following motion traits:

- slow linear movement,
- left to right core shifts, and
- retreating motion when faced with disgust.

Disgust is designed to have a regular sinusoidal movement with an unchanging time period. The forward speed is kept constant. All these features are designed this way to make the robot look indifferent and disgusted of its surroundings. The green color of Disgust is chosen to be RGB (78, 153, 81). The eyes are shaped as the lower-half of a circle.

Neutral

The neutral design is created to act as a control character. We envisioned that this character should mimic stereotypical "robotic" behavior:

- even, linear movement,
- direct pathway, and
- no unnecessary change in orientation.

To achieve this, we gave it blank (or lack of) eyes and color it grey with an RGB value of (175, 175, 175). We add a sinusoidal wave with a very small amplitude to its vertical motion.

FUTURE USER STUDIES

We can study user perception of the robot movements through methodical user studies. The robot designs can be assigned labels that correspond to the emotion depicted by the character they were modeled after. Participants can be asked to watch their movement and rate the label on some scale. Since the virtual robots are modeled after *Inside Out* characters that embody emotions, a high rating would possibly mean a validation of the contrived robot movement. A free response field can be used to affirm this notion.

The user studies will be divided into groups. The first group will be used to test the validity of the robot designs. Perhaps, a second group will be used to study priming as an alternative means of context creation and its effect on the user perception of the robot motion. The third group will be

used to investigate if changing environments has an influence on this perception of motion, which has been shown in prior studies [1]. These environments are created in Unity3D and can be seen in Figure 3.

CONCLUSIONS

This paper presents the design of six virtual robot figures and accompanying motion. The movement of six animated characters was analyzed in order to design these artificial embodiments. Future work will test perceptions of these systems in various distinct environments relevant to human-facing contexts, and the design of these environments has also been presented. Our work is leveraging movement analysis and virtual reality to better understand how humans may perceive robotic motion in their everyday environments.

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