Touch Perception and Emotional Appraisal for a Virtual Agent

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Abstract. Building virtual agents that are able to perceive and appraise touch increase the lifelikeness and interaction possibilities in human computer interaction. In this paper we introduce work on how a sense of touch was realized for the virtual human Max and how he can emotionally react to it by appraising the different kinds of tactile sensation.

1 Introduction and Related Work

Virtual agents have found various attention in affective computing. For instance, agents have been built that can express emotions in their faces, e.g. [4] and voices, e.g. [3]. Also physical agents were developed that can perceive touch and are able to respond to tactile sensations in different ways, e.g. [9] and [10]. An interesting research question is how to develop virtual agents that have a 'sense of touch', in that they could perceive touch and emotionally appraise it. The context for our research is the virtual agent Max [6] that has been equipped with a dynamic emotion system, which can respond to various kinds of stimuli from verbal input, goal achievement or failure [2]. In a first experimental system, Max was equipped with a simple sense of touch that could evoke valenced reactions. In this scenario

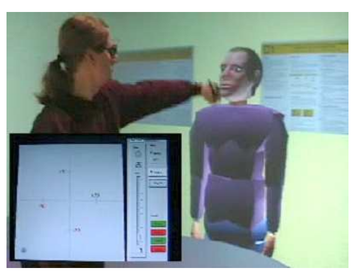

Fig. 1. When touched on his right cheek, Max reacts with negatively valenced emotional impulses.

human users can interact with the graphical representation of Max in a CAVE-like VR environment by means of motion tracking of their hands (Figure 1). The user's hand movements are tracked in order to detect the distance between the hands and the three dimensional geometries forming Max's face. In this first system, touching Max's left cheek gave a positive appraisal and touching Max's right cheek gave a negative appraisal. The stimuli thus elicit emotions that can fortify or alleviate Max's state of mood, which in turn causes Max to display corresponding facial (happy or annoyed) expressions.

In this first setting, the quality of touch could not be differentiated, that is, a touch of the cheek caused an undifferentiated 'all-or-nothing' reaction. In human interaction, however, touch influences emotions in many more subtle ways. Someone gently stroking our arm might evoke happiness in us, while getting beaten puts us immediately in a negative emotional state. On the other hand, touch can also bear a communicative meaning in that someone might want to convey his or her emotions that he or she likes us. Could such a distinguished touch perception and corresponding emotional appraisal also be possible for a virtual agent? In this paper, we describe how touch receptors were developed and technically realized for Max's virtual body. These receptors allow for differentiating between different qualities of tactile stimulation. That way Max can be enabled to extract and emotionally response to the affective content of a tactile stimulation, exceeding the simple all-or-nothing reactions that were possible before.

2 A Sense of Touch for Max

The virtual humanoid agent Max is a situated artificial communicator for modeling and researching communicative behavior in natural face-to-face interactions [7]. Findings from studies on the human tactile systems were incorporated to build an artificial sense of touch for Max, which is conceived not only for virtual but for artificial agents in general. When modeling touch, one important distinction to draw is between active and passive touch [5]. Passive touch is the mere sensation of being touched by some other object, whereas in active touch the sensing individual herself evokes the tactile sensation by actively controlling the stimulation. Here, we focus on the affective content of passive touch. That is, we do not care about the agent's attention, intention or motor control, but can focus on the kind of tactile stimuli passively applied to the agent's body.

In our work on modeling and realizing passive touch for Max's whole body [8], each tactile stimulation is associated with three characteristics, namely, *where* on Max's body it was applied, *what* kind of tactile stimulation it was, e.g. stroking or tapping, and *how* it is emotionally appraised. The realization and explanation of these issues are outlined in the following.

2.1 Where is Max Touched

Max has a segmented body, i.e. his virtual graphical embodiment consists of several geometry parts. Around every geometry representing a limb of Max's body,

Fig. 2. The virtual agent Max with the proximity aura (left) and without the proximity aura (right).

17 proximity geometries were added forming a "proximity aura" (see Figure 2). This allows us to make predictions, when an object in the VR environment is approaching Max‘s body. By means of the aura we are also able to identify the body part an object may be going to touch. Below the proximity aura, the surface of Max's body is covered with a virtual "skin". This skin consists of flat quadrangle geometries varying in size, each representing a single skin receptor (shown in Figure 3). The receptors are located on the body in neighbourhoods, which are represented in a somatotopic map (similar to the map in the human brain). This representation encodes the information which body limb a virtual skin receptor is attached to, and it allows to determine in a fine-grained way where Max is being touched. Depending on the location on the body, a tactile stimulation can thus be interpreted differently. For example, Max could be more ticklish under his arms than on his knees.

2.2 How is Max Touched

Instead of different kinds of skin receptors as in the human skin, we propose only one kind of virtual skin receptor for Max for it is sufficient to discriminate between different tactile stimulations. Every object that is graphically represented in our VR environment can cause tactile stimuli on Max's virtual skin. In addition, a motion-tracked human hand is a stimulus source. The simulation of touch is based on detecting collisions (using the V-Collide collision engine) between these two types of geometries, the virtual skin receptors and external objects of the environment. Each geometry's collision with a skin receptor is regarded as tactile stimulus. Specific stimulation patterns arise from the temporal and spatial changes connected to the stimulation. When a stimulus, e.g., is moving continuously over the skin, neighbouring receptors are responding successively over time (Figure 4). This temporal information along with the spatial information about each triggering receptor, extracted from the somatotopic map, allows to classify the stimulation as a continuous touch of the respective body

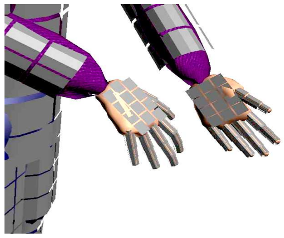

Fig. 3. Virtual skin receptors arranged on the surface of Max's hand. The back of the hand is arranged with 6-neighbourhood receptors, the palm with 8-neighbourhood receptors for higher tactile resolution.

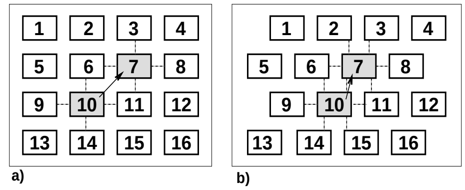

Fig. 4. Schematic depiction of a) eight and b) six neighbouring receptors. Arrows indicate stimuli moving directly from receptor 10 to receptor 7 (highlighted in grey), interpreted as moving tactile stimulus. Dashed lines indicate direct neighbours.

parts. The central component, that fuses these stimulations of the receptors into a coherent touch sensation forms our touch sensor.

For example if a tactile stimulus moves with no spatial interruptions over the agent's body, this can be regarded as light stroking. If a tactile stimulus is applied over a short period of time at one location, this can be interpreted as a short tap.

2.3 Emotional Appraisal

For each classified tactile stimulation we can associate an emotional appraisal. For example, when someone is quickly stroking the bottom part of Max's arm, this is classified as tickling and can be positively (or negatively) appraised. To this end, the touch sensor sends valenced impulses to the emotion system, which drives the emotion dynamics. That is, touch does not directly give rise to specific kinds of emotion, but only controls the number of impulses sent as well as the strength of their valence. This will lead to an increase or decrease of the agent's mood, such that a 'gentle stroke' applied several times can take a comforting effect on Max's mood state. Furher, it is conceivable that the touch sensor can also draw upon informations of the environment, e.g., about the velocity of an object touching Max's body. This would allow to appraise any impact of an object with a high velocity more negatively.

The emotive system is, on the one hand, fed with external stimuli, such as tactile stimuli. On the other hand, the cognitive system exerts influence on the emotional state [1]. In turn, Max's behavior is influenced by his (simulated) emotions, determining as system parameters the way in which Max performs actions. Simulated facial muscles enable him to express emotional states. Max is also able to verbally utter his current emotional states ('I am angry now'). In the case of being hit by a (virtual) ball Max could thus also display or verbalize anger, or he could laugh in the case of someone tickling him.

3 Conclusion

In this paper we introduced an approach to simulate touch perception for the virtual agent Max, based on attaching a large number of virtual skin receptors to his body. Stimulations of these receptors by external objects are calculated in real-time by detecting collisions between the object and, first, Max's "proximity aura" and, then, each single receptor connected to the body part the object is approaching. This method enables a high degree of sensitivity as it was not possible before, neither for virtual agents nor for physical robots. We have presented a way how this perceptual capability can be utilized along with a present emotion simulation system to appraise the tactile stimulations and to accumulate them to determine the "affective content" of touch. Possible applications of this work include a virtual gaming scenario, in which touch perception increases the lifelikeness and interaction possibilities. Human players could touch Max in order to attract his attention or, e.g., could play ball with him. Depending on the quality of the tactile stimulation he could 'feel' a fast moving ball hitting his arm and show an angry face. Another important application is in active touch, where touch perception, goals, and emotional appraisal could be used for Max to develop a form of body awareness.

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