Softly: Simulated Empathic Touch between an Agent and a Human

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I. Introduction

Touch is a sense that is crucial in social interactions but there is a major distinction between the feeling of touch between two humans in the real world, with rich sensations and a believable context, and the feeling of touch in a virtual environment, between an agent and a human. That happens because haptic feedback devices are not very performant at simulating complex human touch. In an attempt to augment human agent communication within virtual
Our investigation is exploring how we can increase the complexity level of sensations generated by a haptic system to create rich interactions with a virtual agent.
Our goal is to create a haptic device that allows the user to feel touched with a social intention and to understand the emotion expressed by the agent touching him. To reach this objective we have built a light, wearable haptic sleeve named Softly that uses an array of voice coils to generate vibrotactile stimuli on the user's skin. We attempt to evoke the feeling of being touched by a human by using two haptic illusions : phantom sensations and apparent tactile motion. We make use of the wide range of frequencies that voice coils can deliver to input more complex signals to try and create a feeling as close to an actual touch as we can.

Traditional haptic devices in virtual environment use vibrating motors and actuators that use vibrations as a way to convey information. However, vibrating motors lack the ability to deliver a wide range of frequencies, they also have the inconvenient of quickly numbing the skin through stimulation. To overcome these limitations, our device uses voice coils that can generate signals in a wide range, which we use to create richer stimulations. This social touch modeling is realised as a part of the ANR SocialTouch project, in which one of the tasks is to propose a decision model allowing an embodied conversational agent in an immersive virtual environment (a CAVE [3]) to touch a human [2]. This led to the design of an overall framework allowing a virtual agent to be touched by and to touch a human, with a decision model focusing on determining when and how to touch, so that the touch will be acceptable and meaningful in the current social situation [1].

II. Related work

Wearable haptic devices have been shown to increase immersion and the ability to maneuver and virtual environment, such as the TactaBoard [7] that was used to create a vest with 16 vibrating motors to improve collision awareness in virtual environments. Other attempts to increase the quality of haptic interactions can be cited, such as [4] which is able to create a sensation of force and movement being applied to the wearer of a pneumatically actuated jacket but with downsides such as the delay to reach complete activation, the heavy and cumbersome air pumps required. Voice coils have also been used in different haptic applications like a stylus with attached voice coils that is able to render complex and microscopic details from textures [8].

III. Presentation of Softly

Our choice to create a sleeve came from the need to choose a highly sensitive part of the body [6] but also one that would not be considered too intimate. The forearm makes for the best candidate as it has a high resolution of mecanoreceptors, making it sensitive enough to perceive complex vibrotactile stimulations. It is also one of the less intimate parts of the body for receiving touch.
In order for the generated stimuli to evoke human touch, we have decided to use something different from most vibrotactile devices. Eccentric rotating mass motors are the most frequent but the vibrations produced are coarse and produce a feeling that is very far from our goal. Linear resonant actuators are slightly better in that regard but not as good as voice coils: speakers without membrane, featuring a neodynium magnet. The major advantage of voice coils is their ability to reproduce almost any signal, as opposed to ERMs and LRAs.

Fig. 1. Acktronika's Hapcoil-one, the voice coils we use for Softly source: Hapcoil-one technical data sheet

To drive the voice coils, we use amplifiers that are controlled by a Bela cape mounted on a BeagleBone Black microcomputer. We use class D amplifiers that have I2C interface and a gain control up to 30dB.

The prototype we built has 6 voice coils mounted as a 2 by 3 grid on the forearm. The amplifiers are soldered on a printed circuit board that is connected to the Bela. Both the printed circuit board and the Bela are powered by a cluster of 4 batteries each. In order for the device to be wearable, the voice coils have been sewn into a tarpaulin fabric that has velcro strips, allowing to fit the device to any size of forearm. The circuit board, the Bela and the batteries are each inside different pockets that were sewn and can be fastened to velcro strips on another tarpaulin fabric support piece. This design makes Softly modular and allows us to make modifications to any individual component without starting from scratch.

To generate a stimulus that is more lifelike than a sine wave produced by an ERM, we generate signals using pink noise, which is why we need voice coils as they are able to produce signals with frequencies between 10 Hz and 10 000 Hz.

In order for the user to feel a continuous touch despite the discrete nature of the grid of actuators, we leverage two haptic illusions. The first is called *phantom sensation* and is produced by activating two actuators in proximity. The effect is that the user feels as if an actuator was located in between the real ones. The second illusion is called *apparent motion*, it happens when two stimuli are in close proximity and with overlapping activation times. The result is that the user feels like there is a single virtual actuator that is moving between physical vibrating points.

These illusions are leveraged in the Tactile Brush algorithm [5] that we have implemented.

The result is a robust, lightweight, adaptable wearable haptic device that can compute touch patterns in real time and wirelessly.

IV. Human-Agent social touch with Softly

Our goal is to be able to use Softly in a real-time human-to-agent interaction in a virtual environment. This means that on top of being able to generate complex signals and delivering them to the user's forearm, it is important that Softly can receive messages from the virtual environment in order to trigger the touches.

We send messages to Softly through the Open Sound Control communication protocol, this lets us send simple messages containing all the parameters needed to compute a touch. To prevent any delay that could be caused by a real time computation of a complex touch, we compute the touches and then store them in a cache on the Bela. This way we make sure that the real-time aspect of the touch is preserved.

To reach that, we need to be able to generate signals to stimulate the user's forearm in real-time. As mentioned previously, we compute the signals thanks to our implementation of the Tactile Brush algorithm directly on the Bela, but the information that a touch needs to be computed and generated cannot come from Softly directly, since there is no tangible entity that will physically touch the user. This is why we use the Open Sound Control protocol to send the relevant information to Softly. This includes the location of the touch, the specific type of touch, the duration, intensity, ramp-up and ramp-down times as well as modulation parameters. Our program takes all of these parameters and outputs a signal sent to the relevant voice coils at the right time. Thus, when integrated with the overall immersive framework, Softly receives from the decision model of the agent a specific information regarding the timing and the type of touch to generate, in accordance with the communicative intention adopted by the agent. This allows us to adequately use different types of haptic signals to express multiple kinds of intentions such as getting the attention of the human, comforting the human, emphasizing on the emotional display of the agent, giving the speech turn or taking it, etc.

V. Conclusions and perspectives

In an attempt to augment human agent communication within virtual environments, we have designed a wearable haptic sleeve. The goal is to allow for the user to feel a touch conveying emotions. Through the use of voice coils we are able to generate signals in a very wide band of frequencies and thanks to the Tactile Brush algorithm implemented on the Bela, it is possible to generate the signals in real time.

We designed and realized an experiment to validate this new haptic interface, as a first step, with classical methods on human perception. Our first results on the haptic sleeve impact are very promising. The haptic illusions create continuous and moving sensations. Some of the signals we selected have elicited answers and reactions producing sensations close to some human touches.

Further experiments will allow us to validate social touch with SOFTLY and the embodied agent in an immersive virtual environment.

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