Haptic Feedback for Improved Positioning of the Hand for Empty Handed Gestural Control

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***Abstract* — The fast development of information technology, which to a large extent deals intensively with human communication, requires a means to integrate gestures into man machine communication. The available CPU power of current computers as well as low cost video devices provide the facilities for tracking human motion by analysis of camera images [5]. In a video tracking environment benefits of mapping freely human gestures to sound and music parameters are often combined with the drawback of a limited feedback to the user. In the case of hand gestures tracked by a video system, a precise positioning of the hand in the gestural space is difficult through the varying bio-motor features of different gestures. In this paper two approaches are proposed for providing a performer with haptic feedback of the hand position whereby the gestural space of the hand is divided in radial and concentric sectors. Two approaches are proposed: a tactile feedback through vibrating actuators and audio feedback through different sound generators.**

I. Tracking of the Hand and Division of the Gestural Space into Sectors

In the experimental configuration the left hand was tracked by a Max/Jitter patch using a video camera. To increase the number of possible gesture actions the position-space of the left hand was divided by an external Max object (*Gitter)* into 9 radial and concentric fields (Fig. 1). The binding of a parameter group to a *Gitter* field was aimed to locate the more important and more often used parameters in the centre of the position space, and parameter groups - less often used - were located around the central area.

II. Tactile Feedback

To improve the positioning of the hand and provide the performer with feedback about the location of the hand, a ring of actuators is proposed, indicating the borders of the *Gitter* regions. Wearing such a feedback unit on the wrist provides intuitive feedback but introduces the problem that the hand position of the wrist alters according to the gesture. To circumvent this problem the mounting of the unit on the upper arm is proposed, which results in a stable sensation for the hand position.

Small tactile feedback units are mounted on the skin giving a sensual feedback of the hand position in the fields defined by the Gitter object. The feedback is realised by small vibrating units. The intensity of the vibration is controllable through a pulse width modulation or an amplitude modulation, which extends the stable frequency approach of Rekimoto, 2001 used in the wristPad. The pulse width modulation circumvents adaptation of the performers perception and provides the possibility for a gradual feedback. Following feedback scenarios are considered for a concentric division of the gesture space into 9 fields.

The concentric Gitter spacing is represented in a concentric distribution of the feedback actuators for the hand:

Indexes of feedback actuators:

(2)

(3) (1)

(4) (wrist-centre) (0)

(5) (7)

(6)

View from the body “through” the hand

III. Feedback Scenarios

Indication of State:

The actual state or the field (Feld) of the Gitter segment that the hand has activated evokes a feedback. In other words the actuator associated with the current active Gitter field is active, for example the leftmost actuator for the leftmost Gitter field.

Indication of Discrete State Transition:

The transition between adjacent Gitter field states is indicated via the feedback of the actuators. The actuators indicate the borders between the Gitter fields. When the hand position comes close to a border the actuator is also activated.

Indication of Absolute Position in the Gitter Field Borders:

Each actuator (in this case 8) is associated with a certain border. i.e. moving from farthest right (body view) to right upper Gitter field rings actuator (1).

The advantage of this approach is that the performer is informed about the absolute position of the hand. The spatial properties of the gesture plane are effectively mapped to feedback on the skin. The drawback of this approach is that an increased number of actuators are needed due to double representation through intrinsic body information of the hand position.

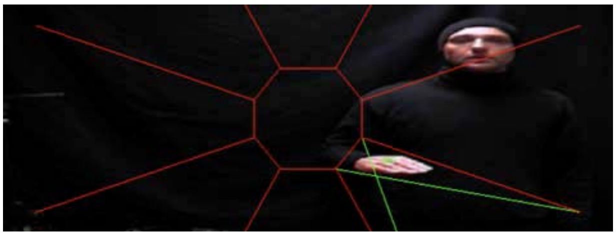

Fig. 1: Seperation of the left hand space into fields (Gitter)

Indication of Relative Position in the Gitter Field Borders:

In this case 8 actuators are used to generate feedback for 8 or less borders, i.e. moving from the inner field to the most right field (subject view) activates the farthest right actuator (0). The advantage of this approach is a finer resolution with reduced amount of hardware. The disadvantage is in increased software implementation effort. For each Gitter field the activation of the feedback generators has to be managed. Additionally the direct mapping of the spatial hand position to the feedback sensation on the skin is lost.

Indication of Continuous State Transition:

Transitions of the hand position between adjacent Gitter fields are mapped to actuator feedback in a continuous border area. The distance to the border is relative to the intensity of the feedback. The advantage is an increased resolution and a improved controllability, the disadvantage: an increased software implementation effort. For each border a start (low) and an end (high) distance has to be defined and the hand position has to be evaluated concerning this distance. The distance is later mapped (scale object) to the output region of values for driving the actuators.

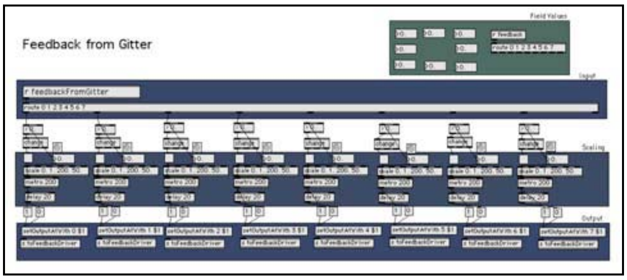

Fig. 2: Max patch for frequency modulation and scaling of the position data of Gitter

The Gitter object needs to indicate a distance from the borders of the Gitter fields. As a measure, the angle for the outer adjacent borders and a distance for the inner adjacent border may be considered. The transition areas are declared for each defined borderline of the outer Gitter fields and for the inner Gitter field. In Fig. 1 the borders for a concentric layout are shown in red. The active field is indicated by a green cross.

The intensity of the feedback is proportional to the distance from the centre. This is, in the following, an inverse behaviour than the rest of the sectors, where the approaching of a border or the leaving of a region increases the intensity of the feedback.

A solution is to reduce the feedback in the centre region and reverse the scaling which means that a larger distance from the centre results in a larger feedback, although the overall feedback level is reduced.

IV. Hardware Implementation

A custom built tactile feedback unit is based on 8 actuators driven by battery powered line drivers and controlled through a commercial available Bluetooth digital to analogue converter box. The actuators are mounted on rubber tie allowing to be applied around the upper arm.

Initial tests revealed that there is no immediate or intuitive integration of the feedback with the *Gitter* object. The sectors at 12 o'clock and 6 o'clock are small and difficult to reach and to feel. A reduced setup omitting the 12 o'clock and 6 o'clock sectors or an even more reduced setup were considered. This could be a flexible, tactile feedback approach used to indicating the active sector only and additional zones by gradually fading into the next sector. Also using the wrist, forearm for the feedback location was considered.

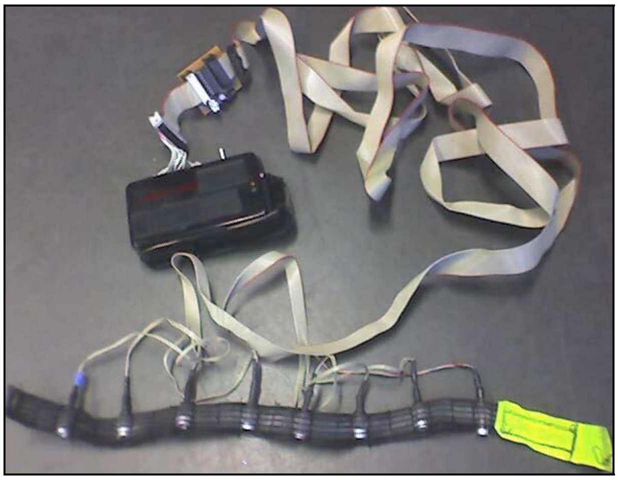

Fig. 3: Tactile feedback unit with Bluetooth receiver

V. Audio Feedback

To reduce the hardware effort necessary for using a tactile feedback device, audio feedback may be considered. Based on the experience of the tactile feedback experiments a similar setup is used to auralise the position of the hand in the *Gitter* context. A drawback of this approach is the interference of the audio feedback with the actual musical environment.

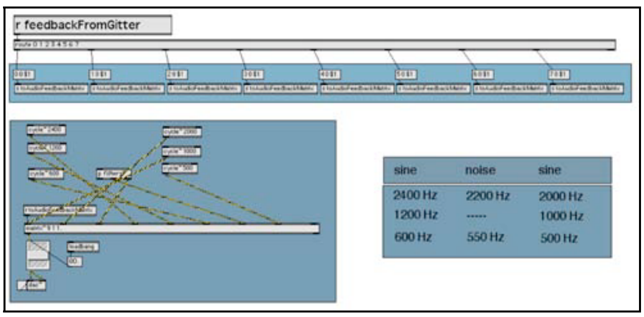

Fig. 4: Feedback by audio signals: sine waves and filtered noise

In the current approach as shown in Fig. 4 sine waves and filtered noise generators are used to map the *Gitter* position to audio feedback. Filtered noise is used for the middle regions of the *Gitter* fields whereas sine waves are used for the left and right outer regions. The vertical position in the *Gitter* fields are mapped to the frequency of the audio generators

VI. RESULTS

The use of haptic feedback increased the precision and speed of the positioning of the hand significantly. With both approaches, the haptic and the audio feedback, it was possible to position the hand in the fields given by the *Gitter* object.

The sensation of the size of the division of the gestural space was such that top, middle and bottom sectors should be larger whereas the left and right sectors should be smaller. The number of sectors maybe reduced to 7 sectors: One centre sector and 7 radial sectors.

The applied feedback mode offered increased tangibility of the hand position in the gesture plane. Only sectors at 1:30, 4:30, 7:30, 10:30 produced a direct, fixed feedback. The centre region produced a special simultaneous feedback pattern on actuators at 12:00, 3:00, 6:00 and 9:00. The spatial resolution of the feedback on the arm skin was more tangible than using one feedback actuator for each sector of the visual plane.

After becoming familiar with the association of the actuator sensation on the upper arm and the position of the hand, it was possible to freely move the hand and at the same time receive the sensation in what actual state the *Gitter* object was or in other words in what field the hand was positioned.

This provided an intuitive sensation of the hand position allowing the producton of gestures without the user being preoccupied by trying to attain the correct orientation within the video frame.

Although a wireless Bluetooth transmission unit was used further developments should aim to provide a more comfortable and smaller solution, which would reduce the effort to attach the cabling and the transmission unit to the performer.

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