3D Theremin: A Novel Approach for Convenient "Point and Click"-Interactions in Vehicles

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ABSTRACT

Efficient and intuitive interaction with screens is a topic of ever increasing importance. The same applies for the car domain, where (i) navigation systems use large screens to provide information, (ii) traditional instrument boards are more and more replaced with fully configurable digital screens, and (iii) novel visual information systems such as the head-up display (HUD) find its way into.

Capacitive proximity sensing has been identified as promising technique to cope with the lack of support for screen content adaptation by proposing eyes-free, contactless human-system interaction in a mouse-like manner. While input with a single or dual dimensional capacitive proximity sensing device has been successfully demonstrated, the extension of the same paradigm to support "point & click" operations in 3D is a novelty discussed in this work.

Categories and Subject Descriptors

H [**Information Systems**]: H.5 Information Interfaces and Presentation—*H.5.2 User Interfaces*; B [**Hardware**]: B.4 Input/Output and Data Communications—*B.4.2 Input/Output Devices*

Keywords

Point & click interaction, Intuitive input, Eyes-free operation, Capacitive proximity sensing

1. NATURAL USER INTERACTION

Natural inspired interaction has recently evolved and some approaches toward this research direction have already been proposed and discussed. Currently established interfaces of this type are operating for example on (i) voice commands, (ii) viewing direction (gaze), (iii) static/dynamic gestures extracted from RGB images or depth video streams, or (iv) sitting posters recognized with pressure sensors integrated into the seating. Each of these solutions shows great potential in certain, restricted situations, but reveals major drawbacks on general use.

1.1 Finger/hand tracking using "theremins"

Capacitive proximity sensing (the "theremin" was the first musical instrument operating on this principle, i. e., was played without being touched) allows for eyes-free and contactless user interaction and is independent from interfering light conditions (darkness, sunlight) or a constrictive soundscape. We anticipate lot of potential of this technology for in-car application. Actually, input devices adopting this principle, for example by tracking finger/hand movements in front of the antennae, have been shown recently. [1] used a one-dimensional version of a theremin in a vehicular environment to study micro-gesture recognition in the steering wheel area and achieved recognition rates of up to 64% in an alphabet of ten gestures. A 2-dimensional theremin was used by [3] to study implicit, natural mouse cursor control in an office environment, and this approach was later extended to the automotive domain by sticking a dual axis theremin onto the gearshift [2]. The input device was used by the pointer finger for mouse-like control of the cursor on a in-car screen. The system achieved good performance in the single task baseline experiment, and showed only little drop in performance under dual task condition.

Device	Intercept a	Slope b	IP
-	*ms*	*ms/bit*	*bits/sec.*
Joystick (worst)	-560	919	1.1
Touchpad (worst)	-194	606	1.6
Theremin (dual task)	**75**	**630**	**1.45**
Theremin (single t.)	**220**	**410**	**1.69**
Mouse (worst)	108	392	2.6
Mouse (best)	1,030	96	10.4
Joystick (best)	-303	199	5.0
Touchpad (best)	181	434	2.3

Table 1: Index of performance (IP) of the dual axis theremin (point only) in comparison to other input devices (point & click), taken from [2].

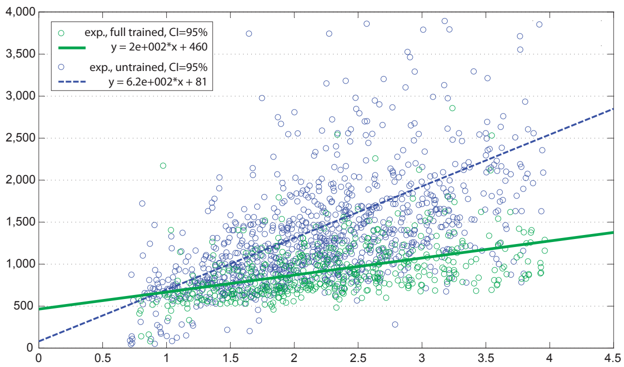

Figure 1: Significant rise in Fitt's law performance after a short training sesssion.

AutomotiveUI'11, November 29-December 2, 2011, Salzburg, Austria.
Adjunct Proceedings

To summarize, "theremins" are suitable devices for implicit input, but a few points have to be considered before their universal and successful application. A dual axis theremin covers a single plane only. Therefore, "point" actions can be reliably tracked but not the common (also in the car needed) "point & click" commands, so that it is recommended to extend the interface to a 3-dimensional setting. Unfortunately, the evaluation or comparison of a 2D setting (Table 1) is biased and cannot be taken as approximation for performance in 3D (i. e., "point & click" application) due to several reasons discussed below. In addition, supported by [3], training has been shown to lead to a significant improved interaction performance (Figure 1), and as a consequence, 3D performance shall be measured with experienced users after some time of training to get close-to-reality, representative results.

2. 3D THEREMIN: A FIRST PROTOTYPE

Revisiting related approaches and taking all the findings into account, we came up with a proposal for a 3D theremin (Figure 2) to allow convenient "point & click" functionality similar to the "mouse move, press button" paradigm. Similar forms of interaction, such as "click & zoom" (e. g., for route navigation), can be easily integrated and provided. The 3D theremin is an extension of our earlier 2D version, adding a third antenna (z axis) orthogonal to the *(x, y)* plane. As we used standard theremins (type PAiA 9505) as underlying hardware, adding a third dimension (antennae) implies to add a second theremin device, with finally four antennae available. In order to better represent the aspect ratio of the common 16:9 screen format in the input space, the remaining fourth antennae was used to extend the range in x axis (one "pointing" to the left, the second to the right). In the current prototype, x and y axis were used for position estimation (*point*), and the z axis, i. e, depth information, was evaluated with respect to *click* actions.

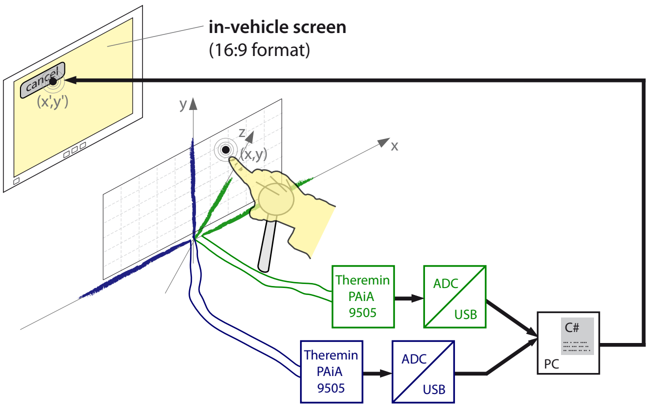

Figure 2: Proximity sensing in 3D: 2 theremin devices, 4 antennae, and extended range in x axis.

2.1 Discussion and further work

First tests with the 3D capacitive proximity sensing device gives hope for reasonable application after applying some modifications and/or extensions. We would like to take advantage of the poster presentation to discuss the open problems with experts in the field of automotive UI design. The most influential technical issues to indicate are

- Interference between the 2 theremins/4 antennae (Figure 2), in particular filtering of "double coordinates" near the point of origin $(0, 0, z)$,
- Optimization of click detection (i. e., adaptation of time window size and coordinate differences in z axis),
- Dynamic recalibration to stabilize cursor position on the screen (as movements across the z axis would cause deviations in x, y sensor values).

Beside these implementation centered problems, some user experience related issues calls for solutions as well.

- Location of the interface in the vehicle (gearshift, steering wheel, dashboard area),
- (Long term) influence of the interaction with the theremin interface on driver's cognitive load (a computer mouse maybe used all day long, but what's about gestural interaction?),
- Capability of pattern recognition techniques (applied to frequent gestures) to improve recognition rate and overall system stability.

Previous experience showed that "point & click" behavior is much better than point only, but also does not cover the full range of possible interaction or input requirements. To address this limitation, the current prototype should be extended and tested with other common tasks such as, for example, the "visual information-seeking mantra" [4]).

3. CONCLUSION

In this work we have shown initial steps toward a novel three dimensional capacitive proximity sensing device able to support common human-system interaction paradigms such as "point & click" or "click & zoom". Successful implementation and transfer of the 3D theremin into the car would open a wide field of possibilities to revolutionize traditional driver-vehicle interaction.

3.1 Acknowledgments

This work is supported under the FP7 ICT Future Enabling Technologies program of the European Commission under grant agreement No 231288 (SOCIONICAL).

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