Rub the *Stane*

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Abstract
Stane is a hand-held interaction device controlled by tactile input: scratching or rubbing textured surfaces and tapping. The system has a range of sensors, including contact microphones, capacitive sensing and inertial sensing, and provides audio and vibrotactile feedback. The surface textures vary around the device, providing perceivably different textures to the user. We demonstrate that the vibration signals generated by stroking and scratching these surfaces can be reliably classified, and can be used as a very cheap to manufacture way to control different aspects of interaction. The system is demonstrated as a control for a music player, and in a mobile spatial interaction scenario.

ACM Classification Keywords
H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

Keywords
Vibration sensing, tactile input, touch interaction

Introduction – sensing touch
Capacitive sensing is widely used to detect the position of touch in touch screens and touch pads. One problem with touch-based interaction has been the poverty of proprioceptive feedback (usually smooth plastic surfaces) during touch interaction, and the lack of

Figure 1: Finger rubbing a rough surface. Vibrations generated by the finger rubbing against the textured surface are sensed by a piezo-microphone.

coupling between the functionality accessed, and the feedback perceived by the user. This requires the user to devote more visual attention to interaction based on touch, and makes it impossible to use reliably in an eyes-free manner. Mobile use of capacitive sensed touch screens is often challenging, and again, in-pocket interaction is almost impossible.

This paper presents an approach to tactile input which uses a hand-held device we call *"Stane"*, from the Scots word for a stone, with a range of textures in the surface design of the case, coupling the physical form of the device with its input controls. The user can stroke, rub, scratch or tap the case to control another device such as a mobile phone, music player or computer. The primary technique investigated in this work involves the use of a piezo-microphone attached to the inside of the plastic device-casing. Vibrations generated by touching, scratching or stroking the case are picked up by the microphone. The basic concept is shown in Figure 1.

This paper is an example of a novel approach to tactile input, and should be of interest to researchers working on input, but it is obviously stimulating to industrial designers, interested in the interplay of physical form and software. The design was developed as a collaboration between researchers interested in fundamental research in HCI, electronics engineers and industrial designers. A patent application has been submitted [6], and the technology should have significant potential for application in the marketplace, due to the low-tech nature of the sensing, and the flexibility in form given to designers. Capacitive sensing cannot work with metal shells, whereas this approach can – useful for aesthetic designs in metal, or more practically for robust and electromagnetically hardened cases. Similarly the avoidance of buttons provides the potential for dust- and water-proof cases.

Related literature

We believe the use of case texture design to explicitly support vibration-controlled interaction is a novel approach to input. PebbleBox [7] is an example of a granular interaction paradigm, in which the manipulation of physical grains of arbitrary material, sensed by a microphone, becomes the basis for interacting with granular sound synthesis models, and there is extensive work on real-time synthesized contact sounds [8]. When we add audio and vibration feedback to the *Stane* it is, in structure, obviously very close to a musical instrument, so we would expect to find elements in the literature close to these concepts. The main difference is the direct use of the classification of inputs to explicitly control a computer. [3] describe the *Soap* device, which allows mid-air interaction via rubbing motions, detected using a standard mouse optical sensor, but with no variation in tactile feedback according to function. The *Tangible Acoustic Interfaces for Computer-Human Interaction* research project used sound to infer user position when tapping or stroking [4], using multiple microphones and high sample rates, while [1] is closer to the work in this paper, focusing on fingerprinting sounds generated by rubbing interactions. [5] used stroking interactions with tactile objects, but with conventional capacitive and force sensing.

***Stane* design**

A prototype was investigated to test different aspects of the design. It was designed in Solidworks and created using SLA resin 3D-printing technology. Inside the outer shell we use the Bluetooth SHAKE (Sensing

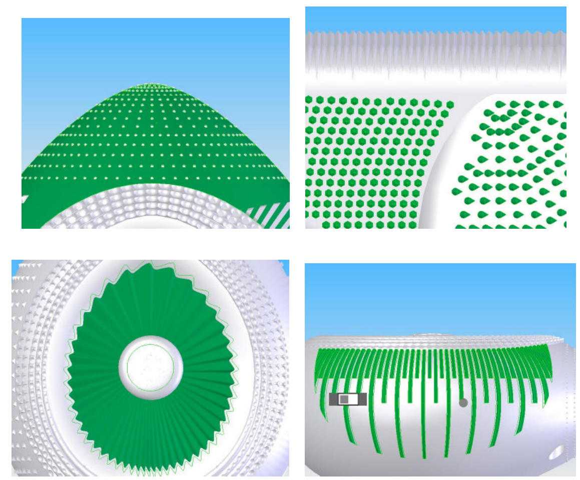
Figure 2: Rigid shell prototype with a range of control surfaces (top). Shell opened to show electronics (bottom). The contact microphone is mounted on the bottom below the two copper pads onto the interior of the device shell.

Hardware Accessory for Kinesthetic Expression) inertial sensor pack for sensing, as described in [9]. The SHAKE model SK6 is a small form-factor wireless sensor-pack with integrated rechargeable battery, approximately the same size as a matchbox (see Figure 2). Communications are over a Bluetooth serial port profile. SHAKE includes a powerful DSP engine, allowing real time linear phase sample rate conversion. The vibrations of the shell are captured with a low cost film-style Piezo contact microphone which is attached to the inner exterior of the body. A custom expansion module was designed for the SHAKE that includes a high-impedance microphone data acquisition circuit and a vibration driver suitable for driving a linear vibration actuator.

Classification of audio signals

The sensed vibrations are classified in real-time, with signals from rubbing different areas of the device assigned to discrete classes. We used a two-stage classification process, with low-level instantaneous classification and higher-level classifiers which aggregate the evidence from the first stage over time. This structure is well suited to real-time audio and vibrotactile feedback which can be a function of instantaneous classifications. These features are sufficient to separate the scratching sounds.

Four different classes are trained; these are: scratching circular front clockwise, scratching dimples on right side, scratching tip with fingernail and a miscellaneous noise class. Each class is trained on 120 seconds of input data, with a range of speeds of motion, and a variety of grip postures and pressures. The way the device is held significantly affects the body resonances of the exterior shell. All data is captured with the shell held in one hand, while being rubbed with the finger of the other hand. In these examples, the surface is stimulated with the back of the fingernail. The noise class includes recordings of the device being manipulated in the hands, being placed in a pocket, picked up and replaced on a table and other background disturbances. We also tested sensitivity to loud noises near the device, but these had negligible effect.



Example textures, with dimples, rotary textures, gradients and ridges with varying frequency, which could be used for e.g. zoom and position control simultaneously. Ridges are especially useful for, e.g. volume control, and can be stroked or picked.

Figure 3 *'ChuckieStanes'* – textures were generated algorithmically to achieve both rich surfaces for storing information for a range of trajectories, and to have desirable aesthetic qualities.

Interaction techniques

The style of interaction with the *Stane* is one where the device is held in one hand, and can either be activated by thumb and fingers of that hand, or in a bimanual fashion using both hands. The user scratches or rubs the device along its various control surfaces and this generates changes in the interaction. Given different textures it is fairly straightforward to have a mapping between these and equivalent key-presses. While possible, and in some cases useful, this is not the primary interaction mechanism envisaged. Stroking motions feel quite different to button-pushes, and are more appropriate for linking to gradual changes in values, such as volume control, zooming, browsing. They are also useful for pushing, pulling and probing actions, and because of the drag in the texture, are a good fit to stretching actions (e.g. zooming). The idea of using this style of interaction is that the user can navigate through a high-dimensional state space, generating incremental changes in state, being pulled or pushed by their stroking actions. The fact that there are many different textures allows control of multiple degrees of freedom in this manner. In many cases it will be interesting to map properties of the variable controlled to the type of texture. This can relate to the perceived nature of the texture, rough, smooth, spiky, compared to the function it controls, and also to the properties of the spacing of elements (e.g. a log-scale on separation for zooming tasks). The structure allows both discrete increments, when the user 'picks' at a single textural component, and continuous ones, when they brush through several. Depending on the parameterisation of the classification dynamics, partial completion of a stroke could give initial preview information about the consequences of continuing that action. If the user then continues the stroke, the threshold is reached, and the associated action is performed.

Augmented feedback

While the proprioceptive feedback inherent in the texture is a key benefit of the technique, it is important that we can augment this with software-controlled audio and vibrotactile feedback. The *Stane* has an in-built pager motor in the SHAKE module, and an additional VBW32 actuator for higher-frequency components. The augmentation of the raw texture with application-specific sound and vibration makes this more feasible, which is why we have partitioned the classification component into multiple levels. The initial classification gives the rough class, and generates a pulse stream to instantaneously drive the audio and vibration synthesis. The augmentation allows us to take the component textures of a specific device, and make them appear to be a range of different media, which invite different styles of interaction, at different rates and rhythms. The user learns the affordances of the Scratch by actively manipulating it, and feeling the changing responses to stroking actions, where each mode of the system is associated with subtle changes in the response behaviour of the system.

Computer generated textures

A wide range of textures can be generated from simple mathematical functions. The specific characteristics of a texture (frequency content, slope shapes, etc.) can be manipulated to create surfaces suitable for generating different types of vibration when rubbed, while maintaining control over the aesthetic qualities of the patterns. The raytracer POVRay was used for texture synthesis, because of its high-quality anti-aliased rendering capabilities and comprehensive language for

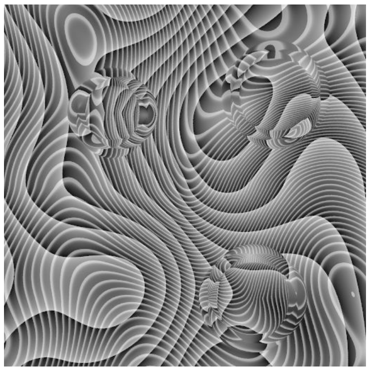
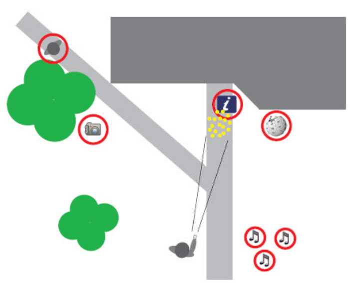


Figure 4 Textures were generated algorithmically to achieve both rich surfaces for storing information – a 'tactile bar code' for a range of trajectories, and to have desirable aesthetic qualities. The *ChuckieStanes* in Figure 3 were created in this manner.

describing textures. Textures are specified as combinations of elementary functions which map spatial (*x,y,z*) locations to grey values. This results in basic patterns such as stripes, dots and spirals. These patterns are then subjected to a series of transformations, including linear spatial transforms like rotation and scaling, nonlinear value mappings and spatial distortions, such as exponential scaling along axes or Perlin-noise based turbulence. Patterns can be composed with simple averaging (e.g. combining logarithmically spaced rules with regularly spaced dots) or with more complex functions (e.g. multiplying two patterns to mask out areas). The resulting patterns range from regular, rigidly geometric forms to realistic substitutes for natural textures such as stone or wood.

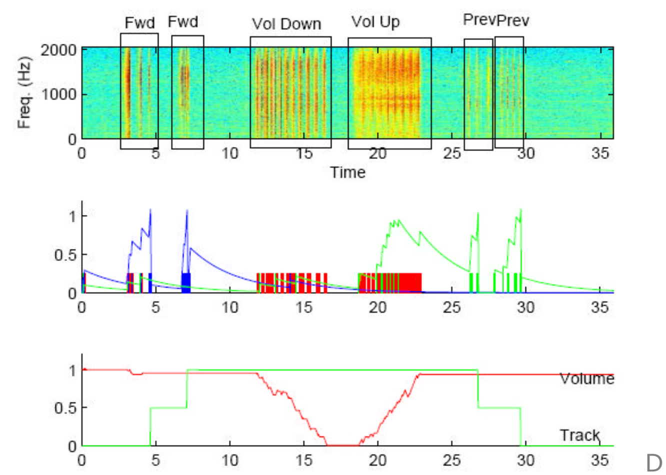
Mobile Spatial interaction

The *Stane* proves to be particularly useful for the emerging field of MSI. With this location-aware instrumented mobile device users can, in the real world, actively point at and engage with content placed in the virtual environment by controlling a virtual probe, scanning the environment using heading data from magnetometers and looking forward and backward using tilt data from its accelerometers as illustrated in the figures below.



Music Player example case study

We have implemented an interface for a music player, which is controlled by scratch-based interaction with appropriate mappings from surfaces to controls. The use case scenario is a user walking, listening to their music player, and controlling the volume and track choice while the Stane is in their jacket pocket. The actions used are start/stop (controlled by tapping), volume adjustment and track change. Each of the classified outputs is fed to an integrator. The output of this integrator is either used directly (for volume control), or is thresholded to activate events (for track changes). This results in reliable control, even though the underlying classification has regular glitches. The textures are easily navigated by the user by touch alone, and the system was tested with five different users, who were able to use it without problems, despite the system being calibrated for a single user.



Data for a session where the user flicks forward two tracks, lowers then raises the volume, then flicks back two tracks. Top plot shows the spectrogram data. Middle plot shows recognition events, and the integrated values from these (dotted lines). Bottom plot shows the changes in controlled variables (volume in red, track in green)

Figure 5: The WayStane. This Stane is used as a pointing device for Mobile Spatial Interaction. A well-defined orientation, planar form and variable textures for both thumb and index finger scraping facilitate the provision of a wide range of interactions. The device is held in the user's hand and tilted to project forward from the current location. The magnetometer in the Shake provides bearing information.

Using the more pointer-like *WayStane* as shown in Figure 5, users can feel content in the virtual environment. They can move content around by pointing, tilting and rolling the Stane and tease out more information from the environment by rubbing the textures. Each texture probes and filters different aspects of content in the augmented space.

Conclusions and Outlook

The technology illustrated in *Stane* allows the use of very cheap sensing hardware, coupled with an arbitrarily textured device case. This technology can compete with or be combined with capacitive sensing, buttons, or inertial sensing. Initial experiments have demonstrated that it is possible to classify stroking movements on a custom designed case, using vibration sensor information alone. The tactile feedback from the physical case is augmented with context-dependent audio and vibration feedback. The texture provides immediate feedback to the user about the likely consequences of their actions, and they can be used in an eyes-free context, such as in the user's pocket.

The simplicity of the case technology provides the potential for user-driven design. Creating 'skins' for mobile devices could become a much more important market than just creating different stylings for the visual appearance of phones - it could also allow designs customized for specific families of applications. We can envisage scenarios where instrument makers create bespoke cases out of materials which allow users to generate their own styles of interaction, with potentially richly expressive and aesthetically pleasing modes of interaction.

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