The Hapticon Editor: A Tool in Support of Haptic Communication Research

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Abstract

We define haptic icons, or "hapticons", as brief programmed forces applied to a user through a haptic interface, with the role of communicating a simple idea in manner similar to visual or auditory icons. In this paper we present the design and implementation of an innovative software tool and graphical interface for the creation and editing of hapticons.

The tool's features include various methods for creating new icons including direct recording of manual trajectories and creation from a choice of basis waveforms; novel direct-manipulation icon editing mechanisms, integrated playback and convenient storage of icons to file. We discuss some ways in which the tool has aided our research in the area of haptic iconography and present an innovative approach for generating and rendering simple textures on a low degree of freedom haptic device using what we call terrain display

1. Introduction

Visual and auditory icons have long been integral to computer interfaces, as a means of indicating functionality, location and other low-dimensional information more efficiently than can displayed text [1,2]. Graphic icons, for example, are small and concise graphic representations of real or abstract objects. These icons should be easily identifiable by the user and can represent a spectrum of information, ranging from specific functions to abstract controls.

In everyday interaction with manual controls such as those found in a car, on a workbench or throughout a building, we use parameters such as shape, texture and muscle memory to identify and locate different functions and states of handles ranging from doorknobs to pencils and radio controls. With the introduction of "active" haptic interfaces, a single handle - e.g. a knob or a joystick - can control several different and perhaps unrelated functions. These multi-function controllers can no longer be differentiated from one another by position, shape or texture differences, and it becomes a design challenge to make both the existence of available functions and their identity apparent to the user. Active haptic icons, or "hapticons", may be able to solve this problem by rendering haptically distinct and meaningful sensations for the different functions.

A systematic approach to hapticon design requires tools that allow people without engineering background closer participation in the creative process, thus broadening and enriching the area. The Hapticon Editor, with its simple, efficient approach, is such a tool.

2. Related Work

2.1. Icon Design

There has been a great deal of work relating to the design of auditory and visual icons. The auditory and haptic iconic design space share many key attributes: they are both temporally sequential, while human perception has narrow limits for amplitude and period discrimination. Thus in our hapticon research program, we have found it most productive to follow auditory icon design.

There have been two principal approaches to using sound to iconify information:

- Gaver et al. [3,4] studied "Auditory Icons". These are essentially representations of the objects or notions that embody a literal, direct meaning: for example, using the sound of a paper being crushed to indicate deleting a computer file. Most of us are familiar with both the sound of crumpling paper and the action of deleting a file, and can easily make the association. While it is an intuitive approach, it does not address whether users can differentiate the icons or how many icons can be distinguished.

- Brewster et al. [5,6] took a different approach. "Earcons" are sounds and rhythms with no innate meaning: their target or meaning must be learned. Brewster's studies have focused on understanding and quantifying the different "Earcons" that can be perceptually differentiated by users, what sounds are most perceptually salient and whether certain sounds are appropriate for a given application. For example, a quiet sound might literally represent a very urgent or dangerous event because that event does not generate much sound in the real world. However, in a different

application, this might be an inappropriate representation.

As an example of a compromise between the two general approaches, the Microsoft Office standard toolbar uses graphical icons in an approach that approximates the literal design criterion. Some of the icons in the toolbar are easily identifiable by most people, yet some others need to be learned.

Our chosen approach to hapticon design is conceptually similar to Brewster's, in its first stage: we experimentally determine where icons should lie in a perceptual sense. For our work, we need to be able to systematically create and test haptic icons; this gave rise to the work presented in this paper.

2.2. Haptic Trajectory Acquisition

There has also been prior work in the area of recording haptic trajectories, a key method of input for the tool described here. The purpose of MacLean's Haptic Camera [8] was to systematically obtain input haptic trajectories for later reproduction. Her system could obtain an approximate model for a real object's haptic response, and play it back. However, the Haptic Camera collected input from passive devices rather than from a human hand, and the force model obtained for the device could be edited only parametrically.

Frei [7] designed a mechanical device that could record trajectories and play them back. His goal was to create an entertaining and pleasing motion when combined and repeated, but not to facilitate editing of the created trajectories. However, the means of input provided some of the inspiration for our work.

Figure 1. The Haptic Display

3. The Hardware Setup

For our ongoing study of haptic icons, we are using a single degree of freedom (DOF) haptic display, configured as a knob (Figure 1). The low-DOF interface is appropriate since we anticipate that haptic icons will be most useful in simple, embedded interfaces rather than in high-end desktop systems. The haptic forces are displayed on the knob by a direct-drive DC motor with an optical encoder for feedback. This research setup employs a closed loop controller situated on a PC and communicating with the hardware through an I/O board.

4. Basics of Operation

The Hapticon Editor works by managing and storing a representation of the haptic forces into files. This allows us to treat haptic sensations as any other digital media.

All operations performed with the Hapticon Editor affect the haptic icon file being currently edited. Each icon is stored in a separate file; and the icon is activated by selecting it from the file list on the top left part of the main screen (Figure 2). When a new file is created by either direct recording or superposition of basic waveforms, it will be added to the file list. The user can perform any of the functions represented in the bottom of the main screen on the active icon, including Play in Time, Play in Space, Record New, Edit, Create New, Add Icons.

The area of the screen showing the sine waveform in Figure 2 presents a graphical representation of the haptic icon being edited. The buttons (graphical icons) on the bottom of the screen represent the available functions for creating and editing an "opened" haptic icon file and will be explained in detail in the following sections.

5. Hapticon Editor Functions

5.1 Creating a New Icon

The Hapticon Editor allows you to create a new haptic icon in two ways:
- Direct recording of the user's motions of the haptic knob (5.1.1.)
- Creation by addition of simple waveforms (5.1.2.)

5.1.1. Direct Motion Recording (Record New button)

This function allows the user to directly store the knob motions. The function records the movements for a specified duration and stores this as positional information in a file for later reproduction or editing.
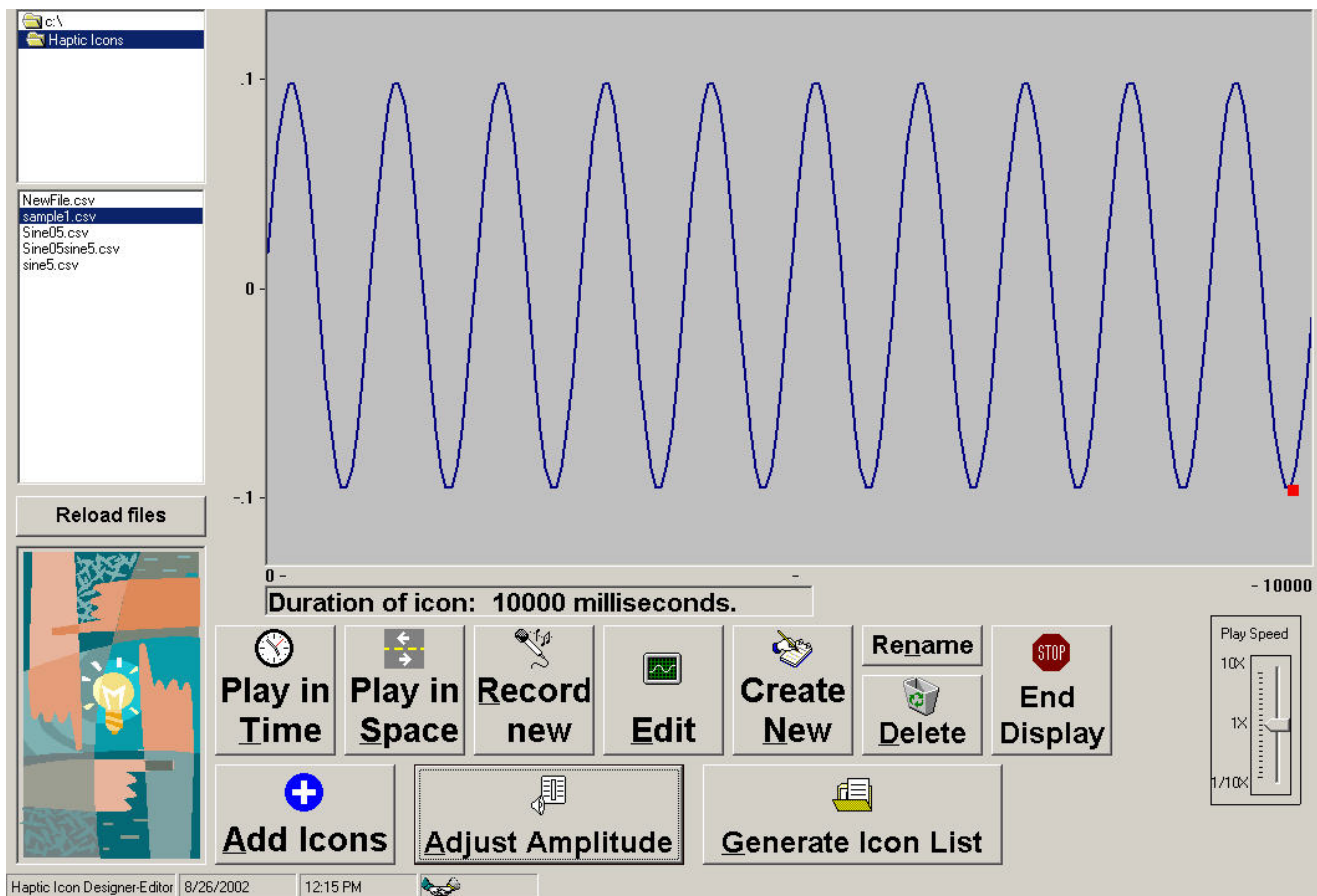
Figure 2. The Hapticon Editor Main Screen.

5.1.2. Creation of Icons From Simple Waveforms (Create New button)

This function allows the user to create a new haptic icon from scratch. The process begins by choosing and appending simple waveforms to create a haptic icon file that can later be displayed through the haptic knob. The icon data is stored in a new file when complete. When activated, the New Icon Screen is displayed (Figure 3).

Figure 3 shows the haptic icon creator screen. The functions in this screen allow the user to generate a new haptic icon by building it from simple waveforms. The total duration for the haptic icon can be specified in milliseconds in the space provided. The user can create the haptic icon using one or more of the given basic functions. Each function is appended one after another. The length, frequency and amplitude for each waveform to be appended can be specified. The graph shown in Figure 3 has been created by concatenating seven simple waveforms of varying amplitudes, frequencies and durations. This file has a total duration of 10 seconds and will be stored with the name <NewFile>.

5.2. Editing Functions

The Hapticon Editor allows you to edit haptic icons in several different ways:

-Adjust Amplitude Function (5.2.1.)

-Graphic Editing of the Hapticon (5.2.2.)

-Hapticon superposing (5.2.3.)

5.2.1. Adjust Amplitude Function

This utility allows the user to either increase or decrease the overall amplitude of a haptic icon by specifying a multiplicative scale factor. This is useful when the overall feel of the haptic icon is either too weak or too strong but you wish to maintain its overall sensation.
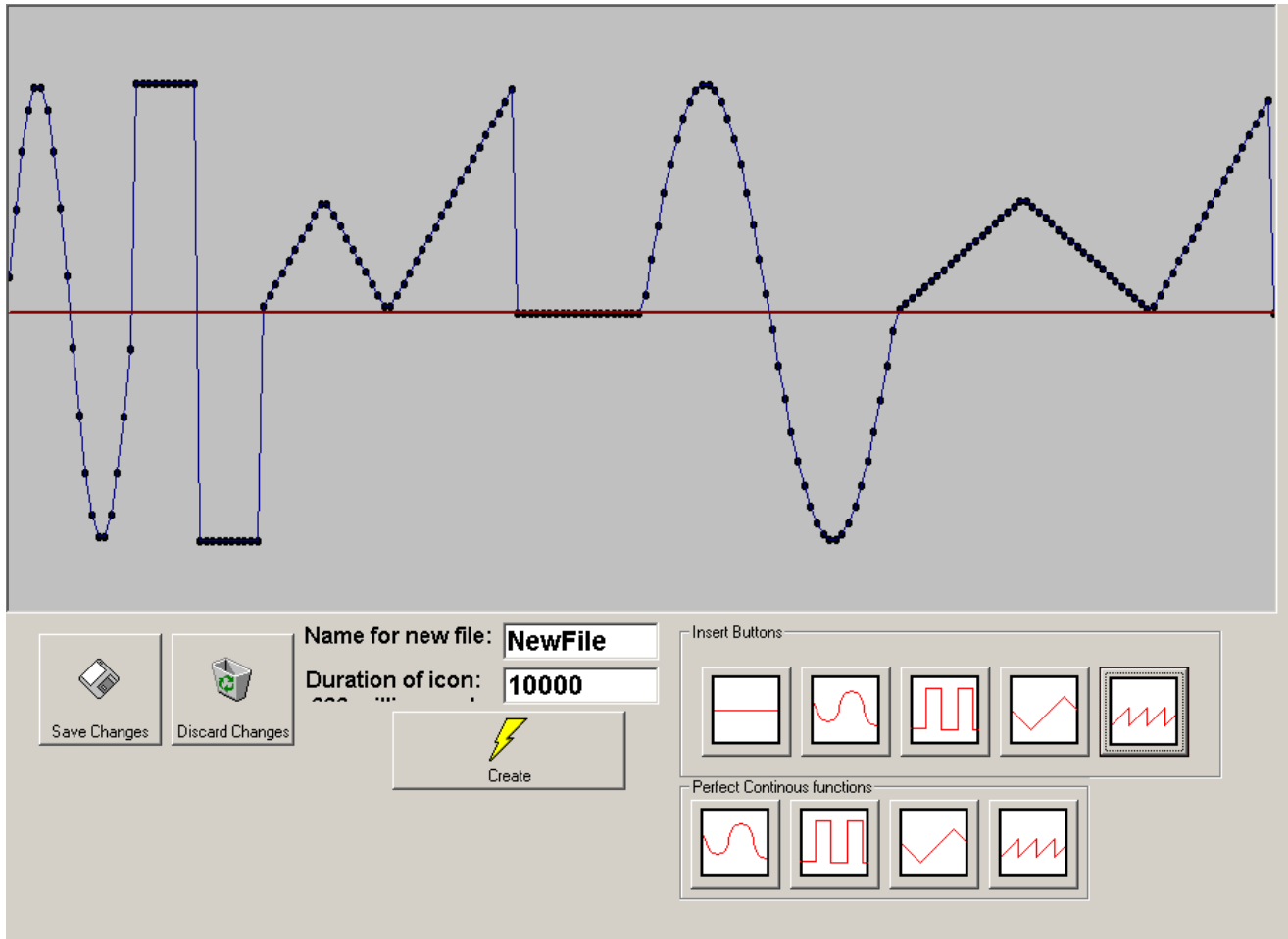
Figure 3. The Hapticon Creator Screen

5.2.2. Haptic Icon Graphic Editor Function (Edit button)

Once a haptic information file has been created, the user can graphically edit the icon using simple mouse commands. Figure 4 shows the graphic editor screen.

This screen shows the haptic icon function as a series of connected dots. Using the mouse, the user can select one or more of these dots and then by moving them, modify the shape of the haptic icon. The selected dots can be moved up or down or set to center using the mouse and the editing functions on the lower right of the editor screen. When more than two dots are selected, moving the mouse up or down moves the selected dots in a parabolic shape with the center dot being moved the most.

5.2.3. Add Icons Function

This utility allows the user to generate new icons by superposing existing icons. Figure 5 shows a capture of the haptic icon adder screen. Combining several simple icons can generate a more complex icon.

Figure 5 shows an icon being generated by superimposing a low frequency sine waveform with a high frequency sine waveform. The resulting waveform can be stored with a name specified by the user. This added functionality allows the user a better palette for creating more complex functions to be used as haptic icons.

5.3. Playback Functions

Creation of haptic icons is a highly iterative process, so it was critical for our tool to have an integrated and very easy to use playback functionality. Once a haptic information file has been created, there are two modes for displaying the file:

-Playback of the haptic icon as a function of time (5.3.1.)

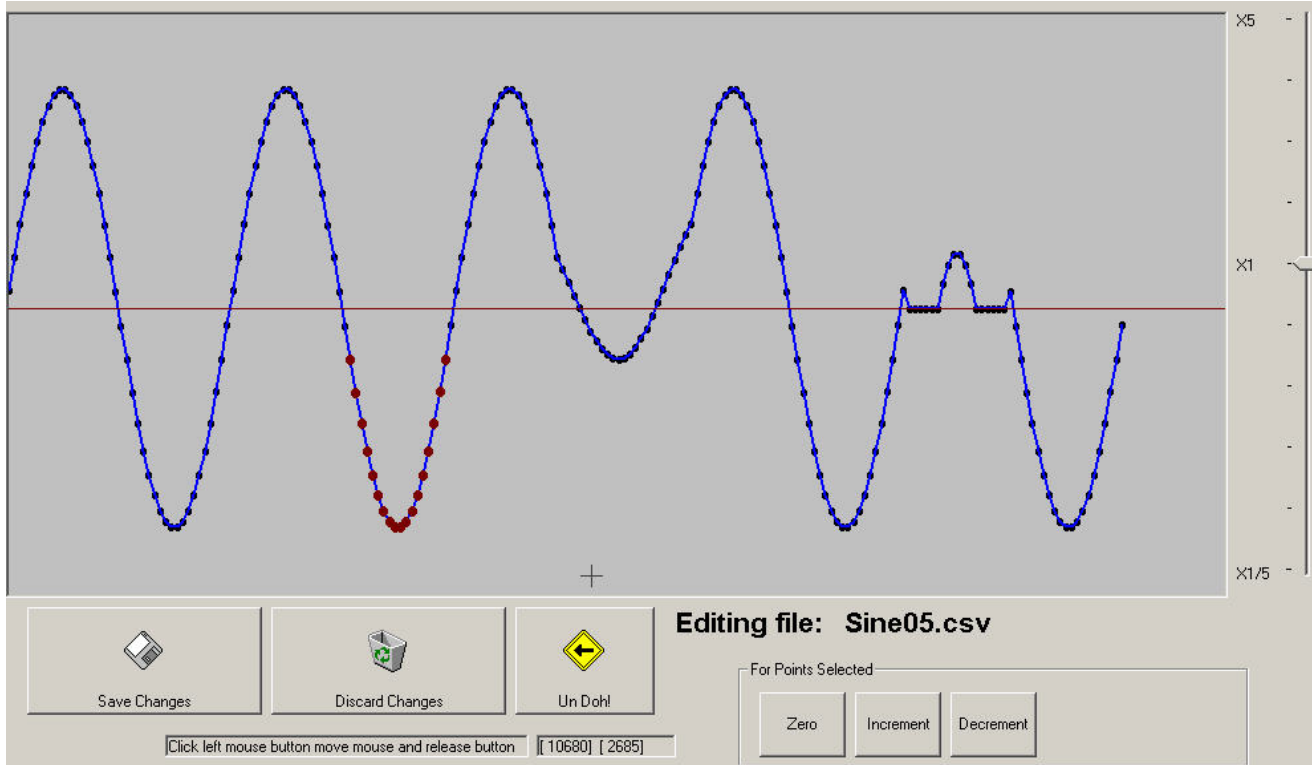-Playback of the haptic icon as a function of knob position (5.3.2.)

Figure 4. The Hapticon Editor Screen

5.3.1. Play in Time Function

This utility displays the previously created/edited icon through the haptic display as a function of time. The icon is displayed by moving the knob to follow the positions indicated by the stored function for a specific time. Play in Time displays the data in the file as forces that vary through time, generating motions on the knob following the graph displayed from left to right.

When a haptic icon was created through direct motion recording, the knob will mimic those motions previously stored. When the icon was created from simple waveforms, the knob will follow the motions specified by the contours of the waveform as a function of time.

This playback method produces what we call passive haptic icons. The user merely holds the knob and feels the forces expressed through it. There is no need for any exploratory motion from the user to perceive this type of haptic icon.

As the haptic icon is being displayed, a small red dot is superposed on the graph showing what part of it is being displayed on the knob at the time.

The Playback Speed slider control, located on the main screen of the Hapticon Editor (Figure 2), allows adjustment of the playback speed for the haptic icons. This allows the user the possibility to record a haptic icon at a slow pace, and then playing it back at a rate faster than it could be manually input. It can also be used to

slow down the reproduction of an icon to obtain a different sensation than the original recording provided.

5.3.2. Play in Space Function

This utility presents the previously created/edited icon through the haptic display as a function of knob position. The user can actively explore the haptic icon, receiving feedback forces that are dependent on the function being displayed and the position of the knob.
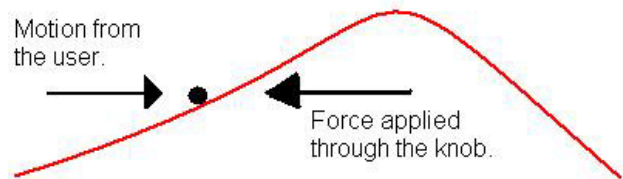

Figure 5. The Play in Space Function Operation

The icon being presented can be explored by rotating the haptic knob, producing force feedback proportional to the inclination of the function at the position specified by the haptic display. This gives the user the sensation of exploring a one-dimensional topographic map.
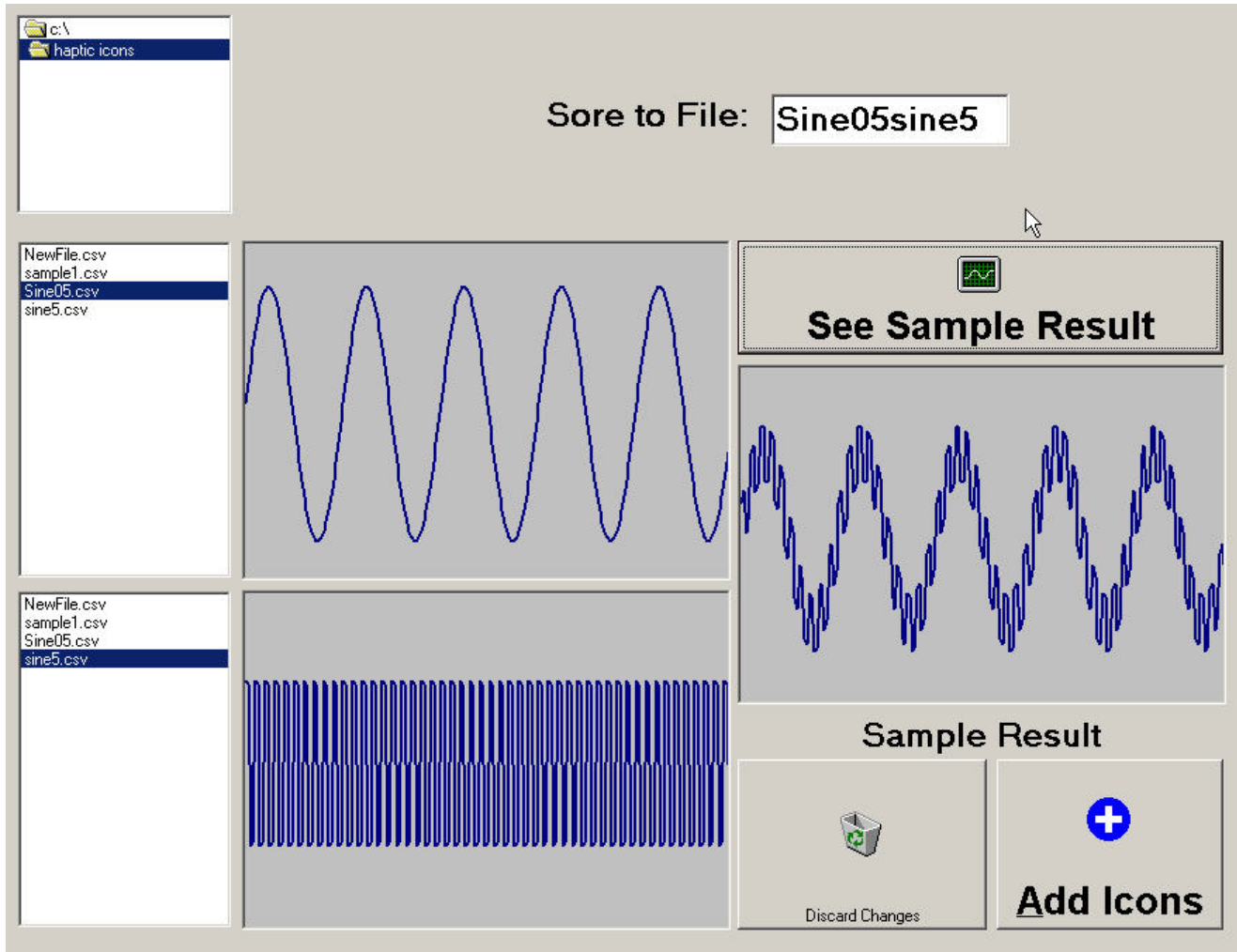
Figure 6. Icon Adder Screen

The knob reproduces the forces that would be felt when pushing a rolling object over the "terrain" of the function displayed. This allows testing of simple haptic textures that can be easily generated with this program.

The main screen displays a superimposed red dot on the graphic representation of the hapticon to allow the user to see what part of the function is being displayed at that specific knob position.

6. Using the Hapticon Editor

The Hapticon Editor has been an invaluable aid in designing and testing a collection of abstract haptic icons that are currently being used to conduct several psychophysical experiments in our lab. Amongst these projects is one that uses an interesting new approach to testing for perceptual differences amongst hapticons [9]. For this work, we study the perception of simple haptic icons utilizing a mathematical exploratory procedure called Multidimensional Scaling Analysis (MDS).

7. Conclusions and Future Work

We have presented a simple tool for creating, editing storing and displaying haptic icons. This tool has been used to aid in our ongoing research on haptic icons for low degree of freedom haptic displays. It has proven to be an invaluable aid for the design and testing of haptic icons.

Our future goals include extending our tool to collect initial trajectory bases from sources other than a human hand, e.g. recording existing controls, switches and rotational textures and later modifying them, thus integrating the benefits of MacLean's Haptic Camera with the current tool. This approach will provide us with a greater diversity and range of motions and forces than available from manual input alone.

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