Using Haptic Feedback to Share Control with a Smart System

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Industrial environments are often saturated with visual and audio stimuli; however, intelligent systems typically assist a user/operator to reach a control goal using visual or audio cues. We posit that haptic interfaces could be used to provide such assistance with less interference, but only if the guidance is provided in an intuitive and non-disruptive way. Using haptic feedback for guidance is not a new concept [3]. For example, force feedback has been most used for providing continuous trajectory guidance directly to the motor control channel [1][2][4].

Our example derives from the metaphor of a haptically rendered elastic string anchored at both ends, which represents the intelligent system's proposed control path. The elasticity constant of the string defines the safe region around this path, which the user moves along as if pulling a bead along a slightly stretchy string. The possible divergence from the "system" path becomes increasingly limited as one moves from the center of the string towards one of the anchoring points. A more complex system-suggested control trajectory could be divided into a reasonable number (*n*) of serially connected string segments, with joints anchored, each with its own defined elastic behavior.

The use of this haptic rendering has several advantages. A human operator can always pull the "bead" to stretch the string to rupture. The intelligent system could then (a) re-assign the trajectory point to another string (control path) leading to a new "safe state"; or (b) suspend haptic feedback and observe the user's subsequent motion until the jump's intention is recognized, then re-calculate the safe trajectories. This second approach has a significant perceptual component: the cessation of haptic feedback gives a sense of freedom (the breaking of a quasi-rigid tie) but also increases the awareness of a higher responsibility (the operator is on his/her own).

A Phantom (Sensable Devices) was used to haptically render a single string in a music-interface example to prototype, evaluate and refine this control approach. A music scenario is a valid testbed for other time-and-safety critical environments such as surgical training or vehicle control: there exist rules that need to be followed in order to generate an aesthetic result, but a musician will create the most satisfying result in performance by creating variations which are in tension with these rules, then finding a way to either return to the original melody or find a new one (i.e. jump to a new trajectory). Furthermore, the music scenario is far easier to simulate and test than a real time-and-safety-critical scenario, with its complex and unsafe stakes and tradeoffs.

The results from a small set of qualitative experiments showed a preference for a system such as the one described as opposed to a more restricted one (in terms of fixed paths and set points that need to be reached) when used to control an expressive performance. These preliminary results validates this method as one of the possible scenarios through which force feedback can be presented to a performer to foster controllability in a music interface.

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