

# Vibrotactile Haptic Feedback for Advanced Prostheses

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## Abstract

The ultimate goal of any prosthetic device is to emulate the form and function of the physiology that it is replacing. Amputees who use upper-limb myoelectric prostheses are severely limited in the haptic feedback they receive from their limbs. If sensory feedback were transmitted through a haptic feedback display, it could lead to improvements in prosthetic control and object manipulation.

Vibrotactile actuators offer a compact, noninvasive solution for a haptic feedback display integrated with prosthetic technology. A pulsing vibrotactile stimulation scheme was developed to represent grasp force of a prosthetic hand. Results from eight able-bodied subjects show that effects of the additional feedback channel are not significant when maintaining object vision. However, there is evidence to suggest that vibrotactile feedback is useful when visual feedback is insufficient in determining grasp force. Furthermore, performance can improve with experience and training.

In a second study, the same vibrotactile stimulation was used in a novel application as the sole biofeedback channel in an EEG motor-imagery Brain-Computer Interface (BCI). Six subjects were tested with this feedback and demonstrated effective BCI control. Furthermore, evidence suggests a bias in motor imagery control was introduced by placement of the vibratory stimulus. The ability of subjects to use haptic information in BCI control supported applying this system to the control of a prosthetic hand, modified to provide sensory feedback.

Vibrotactile stimulation was also used to provide texture feedback to the sole of the foot. The development of this prototype system will enable psychophysical testing for this novel feedback scheme.

In conclusion, vibrotactile feedback can improve prosthesis sensing capabilities as well as closed-loop control strategies. These advances will support the development of advanced prostheses that approach the functionality of the human hand.