Uniformity Based Haptic Alert Network: A Framework for Intuitive, Multi-Device Haptic Notifications

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ABSTRACT
We experience haptic feedback on a wide variety of devices in the modern day, including cellphones, tablets, and smartwatches. However haptic alerts can quickly become disruptive rather than helpful to a user when multiple devices are providing feedback simultaneously or consecutively. Thus in this paper, we propose an intercommunicating, turn-based local network between a user's devices. This will allow a guaranteed minimal time span between device alerts. Additionally, when multiple devices provide a notification-based haptic alert, devices often produce different feedback due to the varying materials they are placed on. To address this, our framework allows devices to self-regulate their levels of haptic responses based on the material density of the surface they are placed on. This allows the framework to enforce a uniform level of haptic feedback across all the surface-device combinations. Finally, we will also utilize this common network to eliminate redundant alerts across devices.

Keywords
haptic alert; haptic feedback; intercommunicating; distributed network; material haptic response

INTRODUCTION
Haptic devices have existed and been significant since the 1970s, however we have only recently started utilizing the full potential of haptics in computing with the Internet of Things revolution. With the rising trend of interconnected devices, technology has been increasingly adopting the use of haptic technology to introduce a new medium of notification for the user. The norm for a user to interact with the device is to engage in a uniform, easy- to-understand manner. Yet as number of devices and applications providing haptic alerts increases, the sheer number of alerts begins to create a disruptive and less meaningful experience.

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HAPTIC ALERT NETWORK
To address these problems, we have developed a novel, self-regulating Haptic Alert Network (HAN) which aims to repurpose standalone haptic devices into a new mesh network of haptic devices acting as an actively self-monitored, intercommunicating alert system. The intercommunicating network has seen prior forms through a zigbee-based system [5], and in prior sensor-based systems [6]. However, our implementation is more integrated with a full set of features rather than just global event notification [7], and is not constrained to any single communication protocol. HAN is a network of haptic devices connected to allow meaningful vibrations, regardless of the surface they are placed on or frequency of alerts. For the system to be non-intrusive and eliminate redundant outputs, we describe an architecture which provides guaranteed minimum separation between alerts, and encourages a less disruptive experience through the reduction of alerts and a uniform level of vibration across all components. Therefore, the user is not overwhelmed with triggered alerts and frequent notifications.

Haptic Equalization

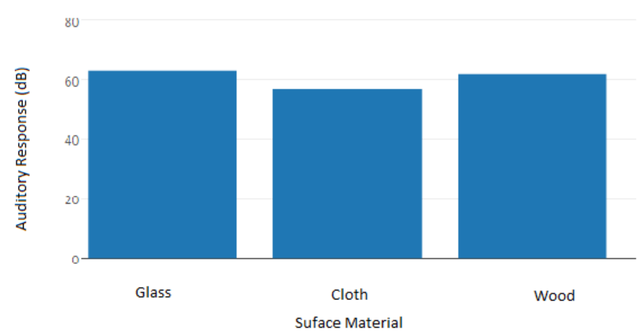

Figure 1: Auditory Response after HAN self-adjustment for uniform vibration levels across all types of tangent surfaces

In the real world, we interact with multiple surfaces including wood, fabric, or granite. If HAN were to act as an intercommunicating alert system for all devices within some constraint, we have to acknowledge how haptic devices will function on different surfaces with varying densities and surface material properties. We base our algorithm on prior work on identifying materials from impact sound level [2,3,8]. To equalize the vibration feedback among different surfaces, we created an equalization algorithm to regulate amplitude and frequency of the vibration motors. The equalization algorithm will first perform a test vibration sample as a control for all the devices in the network. With each vibration, the individual device will measure the ambient sound from the vibration activity. With each control vibration, the individual device will measure the ambient sound, alpha, from the vibration activity. The multiple alphas can all be placed on the x-axis of a logarithmic scale. We use the y-axis of the scale to then determine the average of all the alpha constants. Using the alpha constant average, we can scale up or scale down the power of each haptic device to an average, seen in Figure 1.

The benefit of such an algorithm would be to ensure that devices placed on surfaces with densities on either the very low or very high end of the spectrum can still be perceived as having a uniform level of haptic feedback by the user.

Turn-Based Notification System

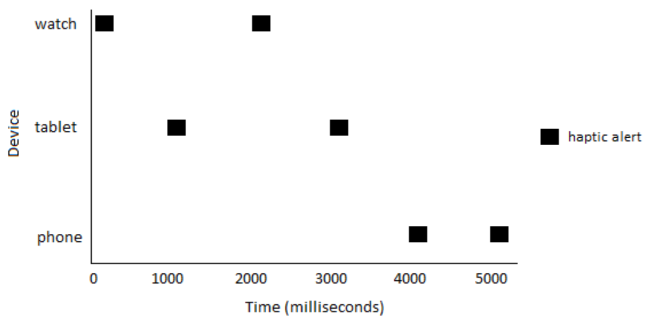

Figure 2: Haptic alert frequency and timing across user's devices with HAN

Through work built upon by Lamport, Ricart, and Agrawala [1,4], we intend to have a network structure between all of a user's devices, over the Bluetooth protocol. This network will regulate a more intuitive, naturally paced sequence of haptic notifications when simultaneous notifications occur. Using the Ricart-Agrawala Distributed Mutual Exclusion Algorithm, each device submits a request to the shared network when it desires to send a haptic notification. It is guaranteed to only receive permission for the critical section if there is no other device in the critical section. Once a device has access to the critical section, it allows the haptic notification to be broadcast. This will completely disallow simultaneous haptic alerts across a user's devices. Our informal experiments show this to present a less frenetic pace of alerts to a user.

Filtering Redundant Notifications

Using the inter-device network we were able to reduce the amount of redundant and simultaneous haptic notifications. Every time a device sends a notification, we register a small amount of metadata into a shared hashmap. The metadata contains time of occurrence and the origin of the notification. Then for any subsequent notifications within the experimentally set time window of 30 seconds, the system will allow a notification to be broadcast only if the hashmap does not already contain an object with the same content. Every time a device enters the critical section and broadcasts a notification, the map is cleared of all objects older than 30 seconds. Thus the system continuously filters for redundancy.

CONCLUSIONS AND FUTURE WORK

The HAN framework has shown to perform well in our informal experiments. It successfully eliminated simultaneous haptic alerts and cut down on the total number of haptic alerts across all devices. The self- regulating algorithm also performed well in adjusting the level of haptic alerts for a uniform haptic response. Future efforts will focus on further optimizing and enhancing the framework. This can be done by supporting additional inter-device communication protocols, and also by using machine-learning for the alert filtering system.

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