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Device to Device Content Transfer Using Orthogonal Haptic Codes

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ABSTRACT

Transferring content such as a link or a photo across devices requires manual steps. For example, such steps may include uploading content to cloud storage from one device and downloading it from the other device, sending the content via email or a messaging app, or pairing the devices via Bluetooth. This disclosure describes secure, single-step, vibration-based techniques of content transfer without explicit device pairing. A transmitting device, e.g., a smartphone, has a haptic motor that is activated to vibrate the device at millimeter amplitude. The vibrations encode the transmitted content, with symbols being selected based on a codebook Upon being touched by a transmitting device, a receiving device, e.g., a laptop, picks up the vibrations on its surface and decodes the transmitted message to recover the content.

KEYWORDS

- Haptic communication
- Vibratory communication
- Tactile communication
- Local content transfer
- Device pairing
- Haptic motor
- Inertial measurement unit (IMU)
- Orthogonal codes
- Codebook
- Neural embedding

BACKGROUND

Transferring a link or a photo across devices, e.g., from mobile phone to laptop, generally requires manual steps such as uploading content to cloud storage from one device and downloading it from the other; sending the content to oneself over email or messaging from one device and reading the email or message from the other; etc. The use of a local network such as Bluetooth doesn't reduce jumping through hoops. For example, use of Bluetooth for data transfer requires connecting and pairing the devices (sometimes with a non-trivial passcode) before the transfer can begin.

DESCRIPTION

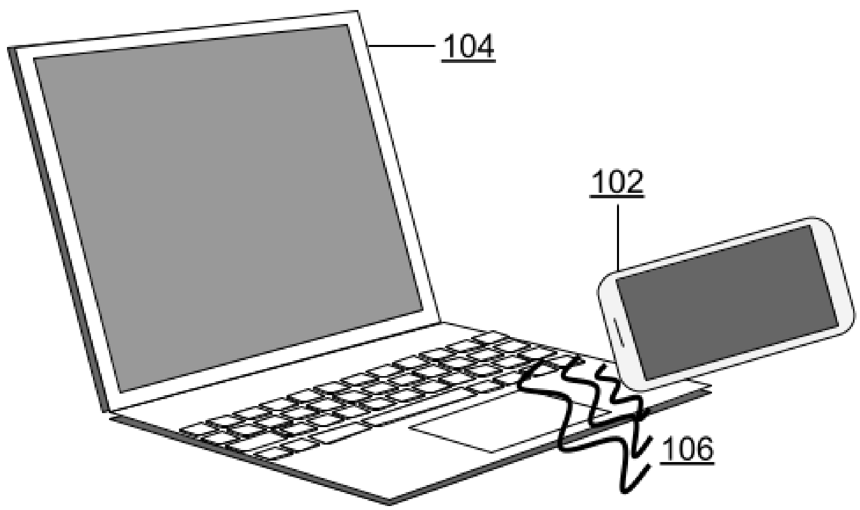

Fig. 1: Content transfer across devices using orthogonal haptic codes

This disclosure describes secure, single-step, vibration-based techniques for content transfer across devices without explicit device pairing. No burden is placed on the user to pair devices; rather, device pairing automatically occurs with content transfer. As illustrated in Fig. 1, a transmitting device (tx, 102), e.g., a smartphone, has a haptic motor that can vibrate the phone at millimeter amplitude, nearly invisible to the naked eye. Such haptic motors are conventionally used to gently notify users of phone calls. Upon being touched by a transmitting device, a receiving or listening device (rx, 104), e.g., a laptop, picks up the subtle vibrations (106) on its surface to decode the transmitted message. The techniques can be implemented in the form of a browser extension, an application, a daemon, etc.

By avoiding messaging in audio frequencies, the techniques sidestep eavesdropping concerns, e.g., an adversarial sniffer listening in audio frequencies cannot intercept the data transfer. Hardening against adversarial sniffing is achieved as follows:

- The haptic motor is vibrational, not acoustic, such that a nearby adversary with a hot microphone is unable to pick up the vibrational effects of the motor, which are transferred only to a listening device in *direct contact* with the phone.
- Rather than use an onboard microphone, the listening device can use a fast inertial measurement unit (IMU) (typically used for orientation/portrait/landscape detection) to pick up vibrations from the transmitter.

In this manner, the techniques leverage the physics of vibrations to effect sniff-proof data transfer. Since over-the-air modalities such as WiFi, acoustic, ultrasonic, etc. are avoided, additional cryptographic layers are unnecessary, although they can still be used. The physical contact automatically provides privacy protection.

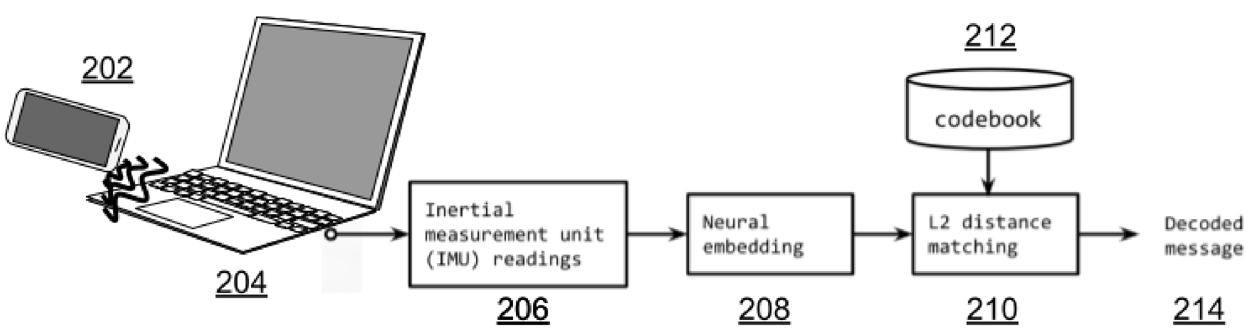

Fig. 2: Processing at the listening device

The overall data flow is illustrated in Fig. 2. The vibrational cue given by the transmitting device (202), e.g., smartphone, to the listening device (204), e.g., laptop, is read by an IMU (206) of the listening device. The IMU signal is buffered and passed to a neural network embedding engine (208) that creates an N-dimensional feature vector summarizing the IMU buffer in a lower-dimensional space.

The feature vector is compared in runtime with vectors in a pre-defined codebook (212). The codebook can contain vectors that define characters of an alphabet. For example, if each bit represents up to 1 ms of activation time, a unique basis (orthogonal) coding such as ‘A’=0001, ‘B’=0010, ‘C’=0011, … can be one candidate way to drive the haptic motor on the phone. The codebook can be trained offline to contain the IMU embeddings for those vibrational patterns received by the receiving device.

The embedding, which can be trained with an L2-distance loss (210), is compared with each element in the codebook. The optimal distance element in the codebook is chosen as the matching embedding. The embedding key is output as the final decoded result (214), for example, the letter ‘A’. This process is repeated multiple times to reconstruct a letter, text, etc. depending on the nature of the content being transferred.

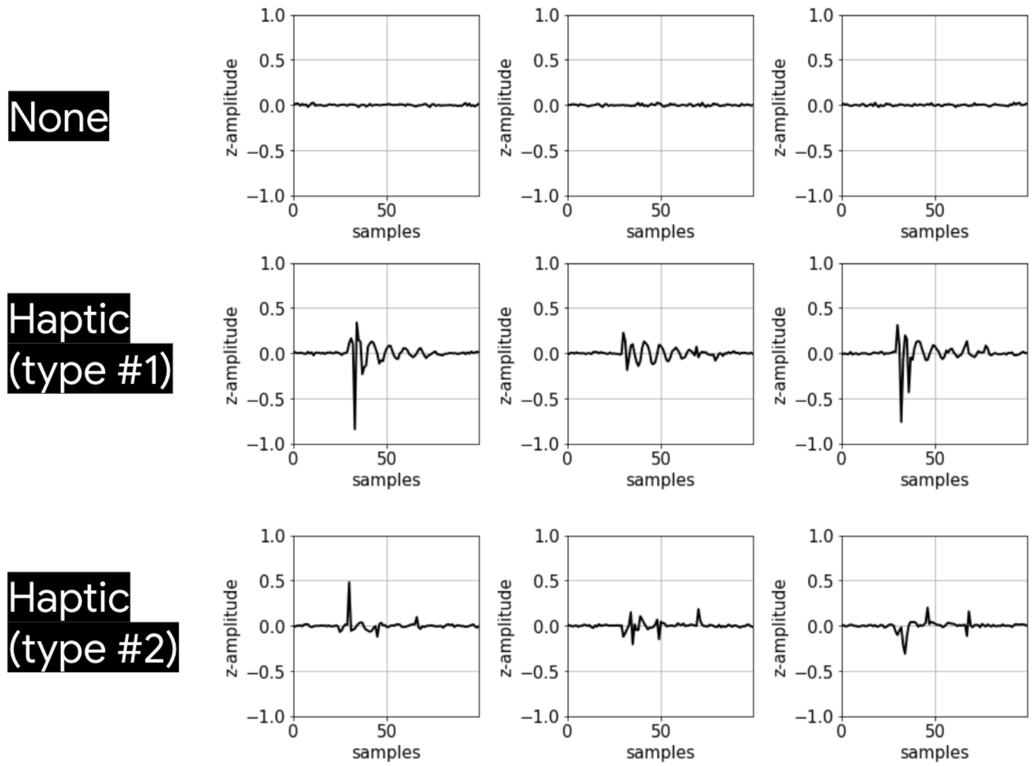

Fig. 3: Haptics motor as an information encoder, and the IMU as a decoder

Fig. 3 illustrates the use of a haptics motor on a transmitting device as an information encoder and the use of an IMU on a listening device as a decoder. When placed on a laptop (receiving device), the smartphone with haptic motor (transmitting device) mechanically jitters the laptop in a subtle way to give rise to non-trivial IMU signals. Different haptics vibrational templates encode different information and application triggers. For example, as illustrated in Fig. 3, haptics type #1 (designated for example as vibrations for an “error” notification) has a z-projected oscillatory IMU signature, while haptics type #2 (designated for example as vibrations for a “warning” notification) has a set of spaced impulses.

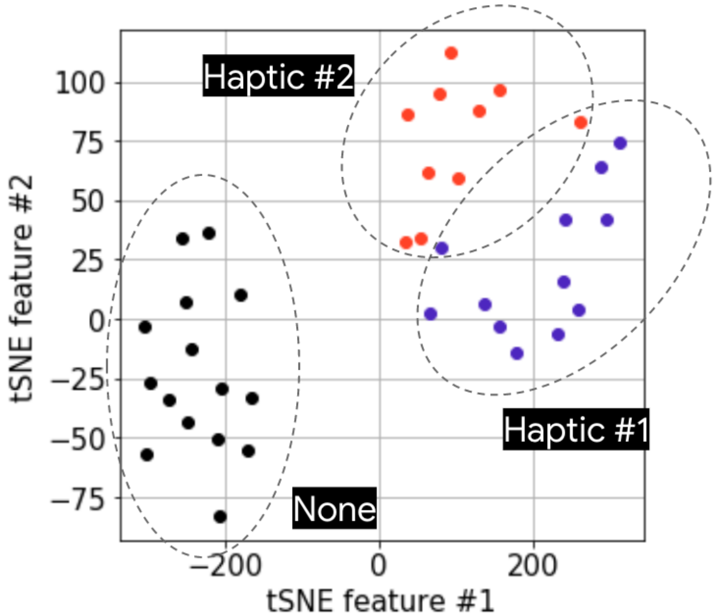

Fig. 4: A tSNE visualization of sampled IMU data

A t-distributed stochastic neighbor embedding (t-SNE) visualization of sampled IMU data, illustrated in Fig. 4, reveals clear separability of haptic signals.

Further to the descriptions above, a user is provided with controls allowing the user to make an election as to both if and when systems, programs, or features described herein may enable the collection of user information (e.g., information about a user's preferences,), and if the user is sent content or communications from a server. In addition, certain data are treated in one or more ways before it is stored or used, so that personally identifiable information is removed. For example, a user's identity may be treated so that no personally identifiable information can be determined for the user, or a user's geographic location may be generalized where location information is obtained (such as to a city, ZIP code, or state level), so that a particular location of a user cannot be determined. Thus, the user has control over what information is collected about the user, how that information is used, and what information is provided to the user.

CONCLUSION

This disclosure describes secure, single-step, vibration-based techniques of content transfer without explicit device pairing. A transmitting device, e.g., a smartphone, has a haptic motor that is activated to vibrate the device at millimeter amplitude. The vibrations encode the transmitted content, with symbols being selected based on a codebook Upon being touched by a transmitting device, a receiving device, e.g., a laptop, picks up the vibrations on its surface and decodes the transmitted message to recover the content.

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