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Fast Recognition of Docked Devices via Impulse Detection and Ultrasonic Handshaking

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ABSTRACT

Docking stations for devices such as smartphones, tablets, and laptops lack convenient mechanisms to recognize specific devices owned by specific users, thus requiring the use of pairing mechanisms. However, conventional pairing mechanisms require precise device positioning and can have a negative impact on design aesthetics. This disclosure describes techniques for quick and convenient pairing between devices and docking stations in a manner that permits docking stations to recognize specific devices. Detection of an inertial impulse trigger is performed via IMUs on devices and docking stations to determine when a device is docked. The initial trigger is followed by an ultrasonic handshake between the device and the docking station using respective speaker-microphone pairs. The ultrasonic handshake is used to recognize specific devices via a secure phase-modulated key that is unique for each device.

KEYWORDS

- Device pairing
- Ultrasonic pairing
- Ultrasonic handshake
- Device recognition
- Inertial Measurement Unit (IMU)
- Docking station
- Vibration impulse
- Event classifier
- Principal component reduction

BACKGROUND

Docking stations for devices such as smartphones, tablets, and laptops are common. A docking station can serve different purposes such as maintaining the device in a fixed position to support convenient viewing of the screen, charging the device battery, connecting the device to peripherals such as speakers, etc. Some hardware and software features of a device are dependent upon the device being docked in the correct position on a docking station. In such cases, the device-dock combination acts as a synergistic pair. For instance, the combination of a tablet docked on a speaker dock can function as an assistive device, e.g., activated by voice commands and providing responses via the speaker.

Given the portable nature of mobile devices, users typically carry them around even within a domestic space. If the user’s environment, such as the home, workplace, etc., has docking stations available at multiple places, users can choose to dock a device at any conveniently located docking station. For instance, a user can detach a tablet docked in the living room of the user’s home and transport it to another docking station in the kitchen. Later on, the user’s spouse could dock another device to the docking station in the living room.

As the above examples illustrate, users can dock a device to multiple docking stations and multiple devices to the same docking station. However, current docking stations lack convenient mechanisms to recognize specific devices owned by specific users, thus requiring the use of conventional pairing using magnetic, USB, or Near Field Communication (NFC) connections. However, pairing devices to docks using such conventional mechanisms is not particularly suitable for seamless user interaction due to sensitivity to misalignment in device positioning. For instance, the sensitivity of NFC device alignment requires users to pay careful attention to properly aligning the device on the docking station every time the device is docked.

Moreover, some pairing mechanisms can have a negative impact on the design aesthetics of the docking station. For instance, the use of USB requires a visible port and wire that requires compromises in the industrial design of the product.

DESCRIPTION

This disclosure describes techniques for quick and convenient pairing between devices and docking stations in a manner that permits docking stations to recognize specific devices, if permitted by the user. Detection of an inertial impulse trigger is performed via the Inertial Measurement Units (IMUs) on devices and docking stations to determine when users might have docked a device. The initial trigger is followed by an ultrasonic handshake between the device and the docking station using respective speaker-microphone pairs. The ultrasonic handshake is used to recognize specific devices via a secure phase-modulated key that is unique for each device.

When a user docks a device, IMUs within the device and the docking station can detect the miniscule vibrations that occur because of the contact between the device and the dock. The IMU data generated by the vibrations is analyzed to remove background noise from the raw signal, e.g., using an exponential high pass filter. As the device-dock contact typically occurs only in a single spatial dimension, principal component reduction is a heuristic to separate the useful one-dimensional vibration signal from foreground data obtained after the filtering.

The extracted principal component is analyzed using a suitably trained event classifier to detect whether the vibration is a result of an impulse event generated by docking a device. The classifier can be run separately on the device and on the docking station to check temporal alignment between the impulse events detected on each.

However, detection of mutually aligned impulse events on the device and the docking station can result from multiple similar vibrations caused by separate events co-occurring in the vicinity of the dock. For instance, a user placing a device on the table at roughly the same time as another user docking a separate device at a docking station on the same table can potentially cause the vibration from the former to be confused for the latter. To account for this issue, the initially detected impulse event is used as a trigger for further high-resolution device recognition to ensure secure authentication and pairing between the device and the docking station.

The recognition procedure employs the respective speaker-microphone pairs in the device and the docking station to perform an ultrasonic handshake via a secure phase-modulated key. Each device in the user's environment (e.g., a household, an office, etc.) is associated with a different ultrasonic key. The docking station can initiate the handshake by generating an ultrasonic signal. The system clock on the docking station is used to measure the total time for the generated signal to return a response from the device. Simultaneously, the system clock on the device is used to measure the time taken to respond to the received ultrasonic signal. The difference between the two times indicates the time taken by the signal for roundtrip travel in the air between the docking station and the device. The roundtrip travel time determined in such a manner can be used to estimate the distance between the docking station and the device and ensure that the device is within a given radius from the docking station.

Simultaneous or near-simultaneous vibration impulses from multiple devices result in multiple ultrasonic handshakes, one with each of the devices. Since only one of these devices can be docked at a time, only the lowest of the distance estimates resulting from the handshakes can potentially be within the specified radial threshold of the docking station, thus enabling accurate recognition of the specific device to be paired from among the multiple possible devices. Among the possible devices, if the device with the lowest estimated distance from the docking station is within the given radius from the docking station, it is recognized as the one docked for pairing with the docking station.

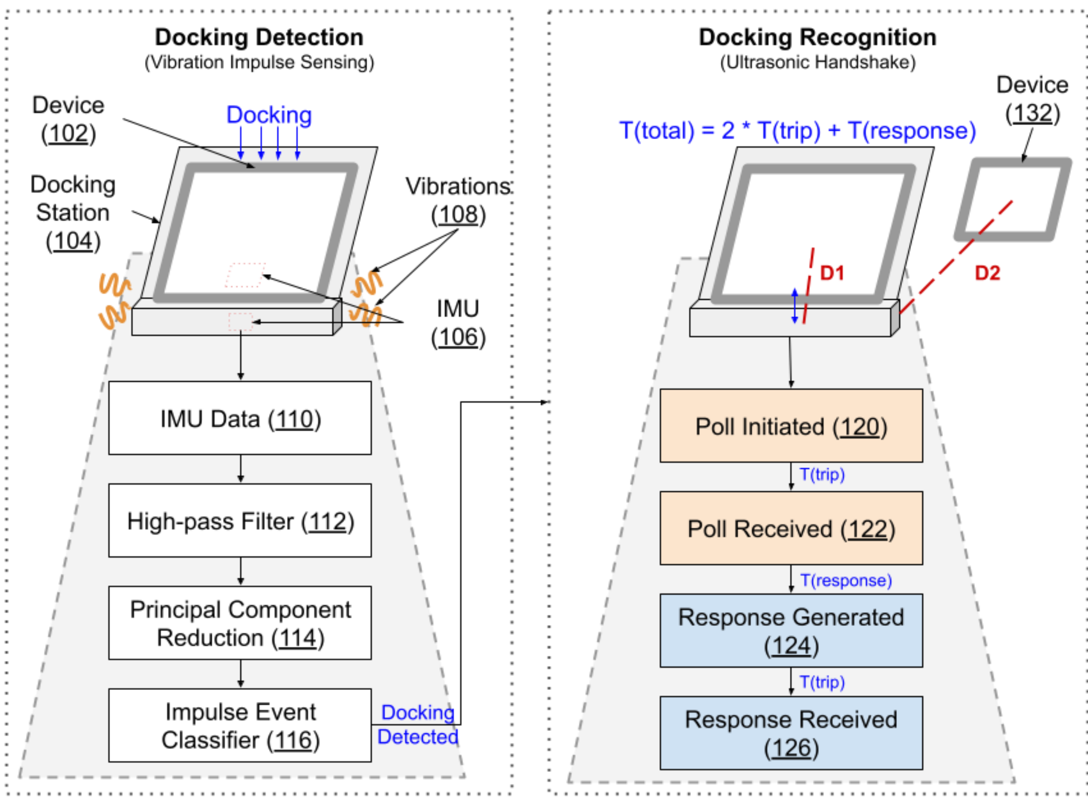

Fig. 1: Recognizing a docked device via impulse sensing and ultrasonic handshake

Fig. 1 shows an example of operational implementation of the techniques described in this disclosure. A user docks a device (102) on a docking station (104) causing vibrations (108) that are captured by IMUs (106) within the device and the docking station. The device and the docking station separately analyze the captured IMU data (110). This includes removing background noise via a high-pass filter (112) followed by extracting the one-dimensional vibration signal via principal component reduction (114). The extracted signal is evaluated by impulse event classifiers (116) within the device and the dock to detect the potential docking event.

The detection triggers an ultrasonic handshake with the docking station speakers initiating an ultrasonic poll signal (120) that is received (122) by the device microphone. In turn, the device microphone produces an ultrasonic response (124) received (126) by the speakers of the docking station. The response time T(response) is subtracted from the total time T(total) for the handshake to obtain the roundtrip time T(trip) for sound to travel in the air between the device and the docking station. The distance between the tablet and the docking station (D1) is estimated based on T(trip). As long as D1 is within a docking radius of the docking station, the docked device is recognized based on its phase-modulated key. If another device (132) also happens to trigger an unrelated vibration impulse at the same time, the ultrasonic handshake with the device results in estimating the distance of the device from the docking station (D2) to be too far to be the device being docked on the docking station.

Device recognition based on ultrasonic handshake as described herein depends on reasonably accurate synchronization between the system clocks on the docking station and the device being recognized. Appropriate synchronization for proper timestamping can be achieved using standard template correlation techniques in which the docking station initiating the handshake and the device responding to it can work out an a priori agreement on the waveform pattern, such as a phase-shifted key used for ping-pong.

The classifier used to process the initial vibration impulses for detecting a potential docking event can be implemented via any suitable techniques, such as a one-dimensional convolutional neural network (CNN) applied on a sliding window of a principal component time series. The model can be trained offline. The various threshold values used for model operation and distance estimates can be set by the developers and/or specified by the users and/or determined dynamically at runtime.

The described pairing technique enables fast recognition of specific devices docked on a docking station that is not sensitive to achieving a finely precise alignment between the device and the docking station. The techniques can be implemented within any device and docking stations equipped with an IMU sensor (e.g., a six-axis IMU sensor), speaker, and microphone within the product enclosure. Therefore, implementation of the techniques requires no additional hardware or wires, thus preserving the design aesthetic of the device and the docking station. Since the required hardware components are already embedded within most common devices and docking stations, the techniques can be implemented in a cost-effective and backward-compatible manner via standard software and/or firmware updates without requiring additional hardware or development of new hardware-based protocols between the device and the docking stations.

Pairing devices and docking stations as described herein can offload the burden of achieving accurate device recognition and pairing between a device and a docking station from the user to ambient devices (docking stations), thus enhancing the user experience (UX) of seamlessly moving, docking, and using devices within environments shared by multiple users.

CONCLUSION

This disclosure describes techniques for quick and convenient pairing between devices and docking stations in a manner that permits docking stations to recognize specific devices. Detection of an inertial impulse trigger is performed via IMUs on devices and docking stations to determine when a device is docked. The initial trigger is followed by an ultrasonic handshake between the device and the docking station using respective speaker-microphone pairs. The ultrasonic handshake is used to recognize specific devices via a secure phase-modulated key that is unique for each device.