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ABSTRACT

Location determination using the global positioning system (GPS) can suffer from signal quality issues caused by multipath effects or signal fading, as well as device-specific GPS-signal integration techniques. Accurate location determination is important for many user tasks. This disclosure describes techniques that enable users to automatically obtain accurate location based on the most accurate location measure among all available devices by using the device(s) with the least noisy GPS signal. Unsupervised clustering of data from device motion sensors can be employed to determine the available devices. Impulse characterization can be used to measure the quality of the location signal by taking into account various noise-inducing factors and to select the device(s) for obtaining the most accurate location determination.

KEYWORDS

- Global positioning system (GPS)
- GPS satellite
- GPS signal
- Location-based services
- Location accuracy
- Motion synchronization
- Impulse characterization

BACKGROUND

Users often carry multiple mobile and/or wearable devices, such as smartphones, smartwatches, fitness bands, tablets, laptops, etc. Many of these devices include capabilities to determine location of the device using the Global Positioning System (GPS). However, GPS signals can be noisy and imprecise because of environmental factors, such as multipath effects created by the signal from GPS satellites bouncing off nearby objects, signal fading because of refraction or movement, device-specific GPS-signal integration techniques, etc. The noise can affect different devices differently. As a result, the accuracy of location determination can vary across devices.

Location determination capabilities enable location-based applications and services, such as receiving directions from the current location, finding nearby places, measuring workouts, etc. Users are often unaware of the factors underlying GPS and their impact on the accuracy of location determination since these are not explicitly indicated in the user interface (UI). Currently, users cannot select the device with the most accurate location determination among the multiple devices they happen to be carrying at a given time.

DESCRIPTION

This disclosure describes techniques that, with user permission, utilize the most accurate location determination among all GPS-capable devices being carried by a user. The devices that are available for location determination at a given time are polled to determine the quality of the GPS signals received by each device. The device(s) with the least noisy GPS signal are used to determine location.

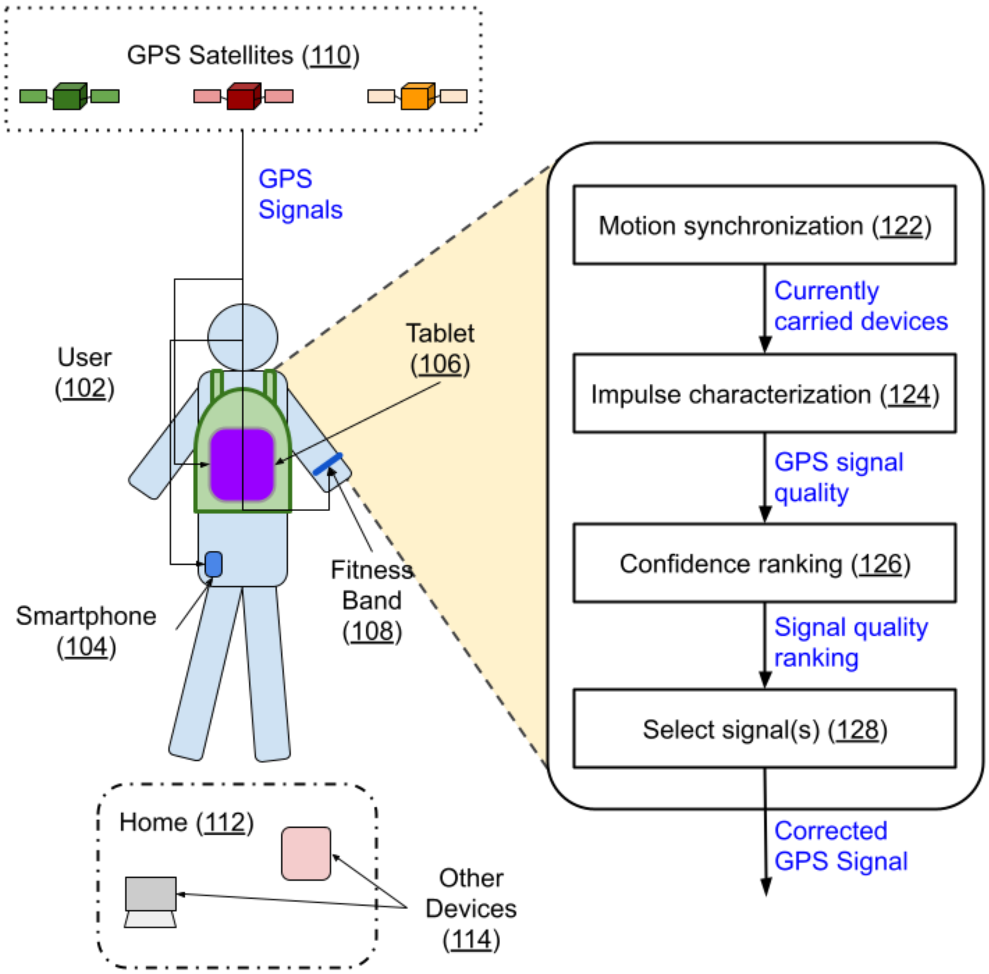

Fig. 1: Determining location using device(s) with the most accurate GPS signal(s)

Fig. 1 shows an example operational implementation of the techniques described in this disclosure. A user (102) is carrying a smartphone (104), table (106), and a fitness band (108) while away from home (112). All three devices are capable of determining location based on received GPS signals from GPS satellites (110). The user wishes to use the location measurements to record the parameters of the current walk as a fitness-related activity.

The devices the user is currently carrying are determined based on synchronization of their motion (122) with the user's motion, such as walking, standing, sitting, etc. In the case of Fig. 1, motion synchronization results in the user's smartphone, tablet, and the fitness band being recognized as those being carried by the user, distinguishing them from the user's other devices (114) currently at home. Subsequently, impulse characterization (124) measures the quality of the GPS signals at each device in terms of signal-to-noise ratio (SNR). The devices are ranked (126) based on the SNR. The ranking is used to select particular signals (128) as the correct GPS signal that provides the most accurate location determination that can be used by any of the three devices the user is carrying.

Impulse characterization can be used to obtain an overall measure of the SNR during signal acquisition that can take into account various noise-inducing factors, such as multipath effects, signal fading, etc. For instance, the SNR can be calculated based on an overall weighted calculation that combines multipath effects and signal fading. The SNR measures for all devices can be used to determine which of the devices can provide accurate location information and can further be used to rank those devices based on the quality of the GPS signals. Based on the ranking, the correct GPS signals for obtaining the most accurate location determination can be selected as the signals received at the device with the highest SNR or an average of the signals from multiple devices with SNR above a threshold. In case none of the devices have SNR above the specified threshold, the selected GPS signals can be an average of several lower-SNR values. Averaging of multiple signals can be performed in the domain of earth-coordinates.

Synchronization of the user's motion with device motion can be performed by independently polling each of the user's devices for data from the device motion sensors, such as accelerometer, gyroscope, etc. Motion-relevant features, such as frequency range during walking, zero-state energy, etc., can be buffered for a given amount of time, such as one minute. With user permission, the buffered sensor data can be analyzed to classify whether a device is currently carried by the user. Such classification can be performed via unsupervised clustering, such as k-means clustering with k = 2 given that the devices are to be classified into two clusters (carried by the user or not carried by the user).

The techniques described in this disclosure can be implemented to support any GPS-capable devices to improve the accuracy of location determination for any location-based application or service. The techniques can help users benefit from the most accurate location determination possible across all devices currently being carried, without requiring any effort on their part. The improved accuracy of location determination can enhance the user experience (UX) and utility of location-dependent applications and services.

Further to the descriptions above, a user may be provided with controls allowing the user to make an election as to both if and when systems, programs or features described herein may enable collection of user information (e.g., information about a user’s device, social network, social actions or activities, profession, a user’s preferences, or a user’s current location), and if the user is sent content or communications from a server. In addition, certain data may be 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 may have 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 techniques that enable users to automatically obtain accurate location based on the most accurate location measure among all available devices by using the device(s) with the least noisy GPS signal. Unsupervised clustering of data from device motion sensors can be employed to determine the available devices. Impulse characterization can be used to measure the quality of the location signal by taking into account various noise-inducing factors and to select the device(s) for obtaining the most accurate location determination.