Technical Disclosure Commons

Defensive Publications Series

May 2021

Hyper-personalized Wearable Sensor Fusion for Contextual Interaction

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Hyper-personalized Wearable Sensor Fusion for Contextual Interaction

ABSTRACT

Contextual user interactions with devices and applications today are largely confined to context from location or on-screen context, and to the device at hand. This disclosure describes a context framework that, with user permission, integrates wearable and stationary sensor inputs and traditional digital context into a larger computing ecosystem to deliver content across a range of proactive ambient computing use cases. Devices and apps register their sensors with a context engine and send periodic data updates to the engine. Using machine learning models, the context engine updates the user context based on sensor and external data, and provides the user context to registered devices and apps, which modify their behavior or surface content based on the user's context.

KEYWORDS

- Ambient computing
- Context-aware computing
- Contextual content
- Contextual suggestion
- Wearable sensors
- Sensor fusion

BACKGROUND

Contextual user interactions with devices and applications today are largely confined to location and on-screen context. For example, with user permission, user interactions can be contextually informed by the user's GPS data, by the app currently in use, etc. With this somewhat limited understanding of context, location or time-based experiences (e.g., commute, local recommendations) or on-screen suggestions can be made. Device-centric computing, combined with limited input signals, means that contextual experiences are rare and are confined to the device at hand. For example, while a user's cell phone may be able to infer that they are driving and therefore automatically enter a do-not-disturb mode, such information is not available to affect experiences across the user's other devices.

Although integrated device ecosystems do exist in the market, these don't have state management, e.g., only take the contextual signals at hand and generate suggestions in notifications. An example is a suggestion to turn off lights, issued mechanically every night at a certain time, without determination of whether the user is actually ready to go to bed.

Context categories for use within ambient computing are built using machine learning (e.g., whether the user is "home" or "away"), but these typically include just the location coordinates of the user's phone and movement sensing from stationary devices. Context categories that describe a user's digital behavior or physical activities, again, typically don't use inputs beyond location.

DESCRIPTION

Wearable computing, particularly with multiple wearable devices, opens up an opportunity for hyper-personalized location and activity detection that can greatly improve contextual understanding and content delivery. This disclosure describes a context framework that, with specific user permission, integrates wearable sensor inputs and traditional digital context into a larger computing ecosystem to deliver content across a range of proactive ambient computing use cases. The context framework enables the creation of new types of context-aware experiences.

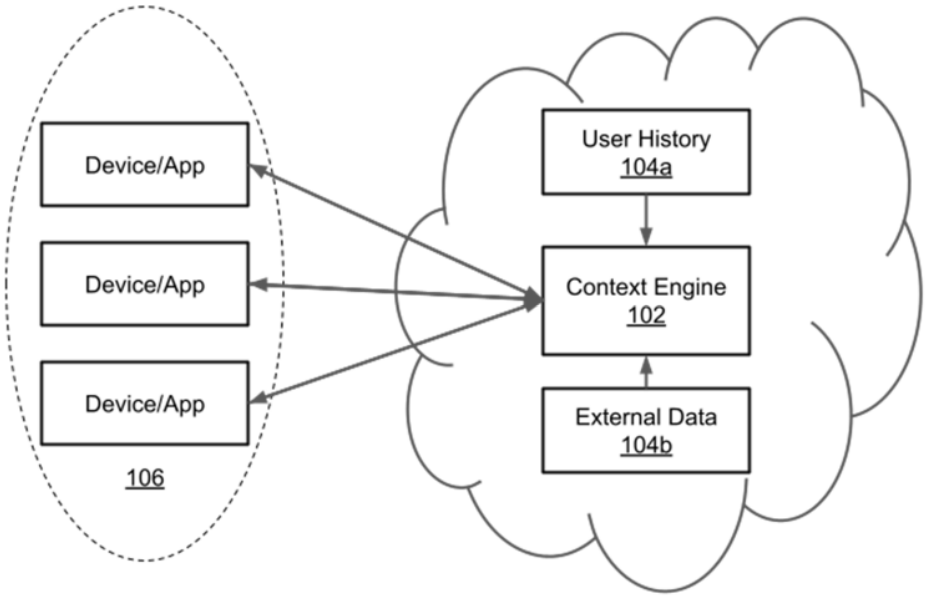

Fig. 1: The context engine

Fig. 1 illustrates a context engine, which can be implemented in the cloud, as illustrated, or locally. The context engine (102), or framework, unifies, with user permission, many digital and physical signals (104a-b), including those coming from wearable and stationary devices (106), to provide a rich picture of a user's current context and enable proactive use for ambient computing.

Information from the context engine can be used by the devices (106), e.g., by the device operating system, to suggest utilities or information that might be most relevant to the user at a particular time, or by a virtual assistant as input for better task completion. With user permission, the information can also be used by specific applications to adapt their behavior and the content they surface to the user. For example, near bedtime, a device might help the user wind down with tips based on the amount of physical activity and sunlight exposure that day, which are gathered via other, wearable devices.

Devices and apps register with the context engine to receive context updates and to send data updates. During registration, devices and apps declare their capabilities and requirements to the context engine, e.g., what sensors they have (camera, temperature, etc.); what types of context components they can provide; what inferred contexts they want to consume (e.g., what activity the user is performing); etc. Sensing data sent from the device to the context engine can be at various levels of abstraction, e.g., in order of contextual knowledge,

- user is touching coordinates (534, 493);
- user is interacting with a device;
- movement is detected;
- Joanne is seen in the dining room;
- user is now asleep;
- user is cutting food; etc.

Sensing data can be sent at different rates, e.g., upon certain events (e.g., when the user begins running); at fixed intervals (e.g., the user's average heart rate over the last minute); etc. A single device can send different types of data at different rates. A confidence measure can be sent alongside the data, e.g., "Joanne is seen in the dining room; high certainty."

Aside from incorporating traditional models of user context that reflect a user's digital actions, the context engine also incorporates user context information gathered with user permission from an analysis of wearable device signals, e.g., biometrics, worn camera input, etc., as well as signals from other smart devices the user makes use of. The inferred user context is updated by the context engine and broadcast to registered devices or apps.

Some example categories of user context, generated and brought together in the context engine with user permission, can include:

- A user's current activity and tasks (can include physical activities and/or digital activities). Examples of physical activities include cooking; jogging; grocery shopping; sitting on a couch watching TV; etc. Examples of digital activities include viewing a cooking tutorial; playing a workout playlist; checking email; working on a presentation; etc.
- The user's intents and goals. Examples of intents and goals include unlocking the front door; baking a cake; buying a gift; finishing a presentation; etc.
- The user's physical and emotional state. Indicators of physical and emotional health include heart rate; body temperature; stress level; amount of sleep; recent safety history, e.g., falls, accidents, etc. Some examples of physical state include sleeping; working out; working; focused; interacting with a specific device; etc.
- The user's physical environment, including location, details of nearby devices, objects, WiFi networks, and people near the user, etc. The location can be at various granularities, e.g., GPS coordinates; house/work/car; specific room in a building; etc.
- The user's digital behavior, e.g., preferences, history, content, etc.
- External data such as date, time, weather, traffic, etc.

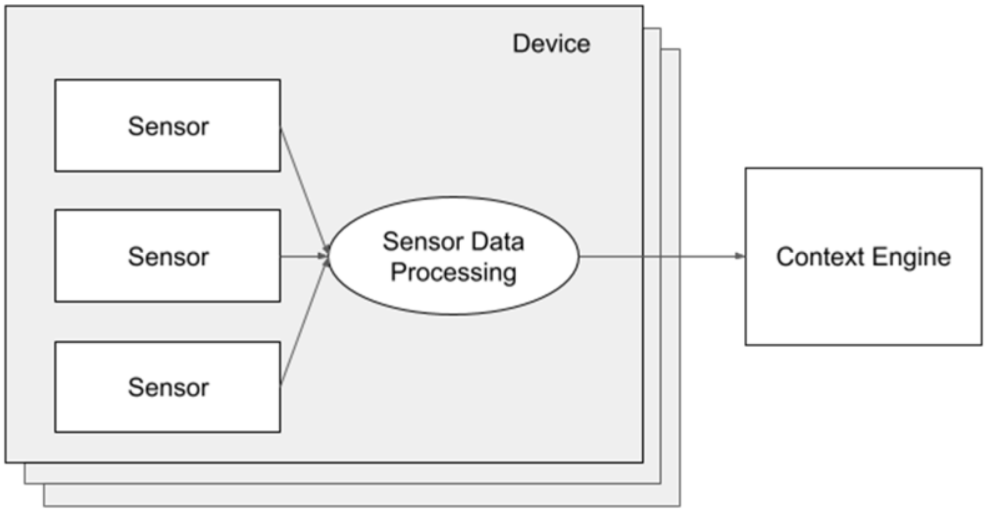

Fig. 2: Sensor data fusion

As illustrated in Fig. 2, the above information is typically inferred from combinations, or fusions, of multiple signals (and potentially from multiple devices). For example, determining a user's current activity/task can incorporate combinations of:

- movement sensors on worn or carried devices;
- biometric signals from worn devices;
- visual sensors on worn or nearby devices;
- audio analysis from worn or nearby devices;
- location data from worn or carried devices;
- time of day/day of week information;
- recent searches or virtual assistant queries;
- prior user behavior (digital and physical); etc.

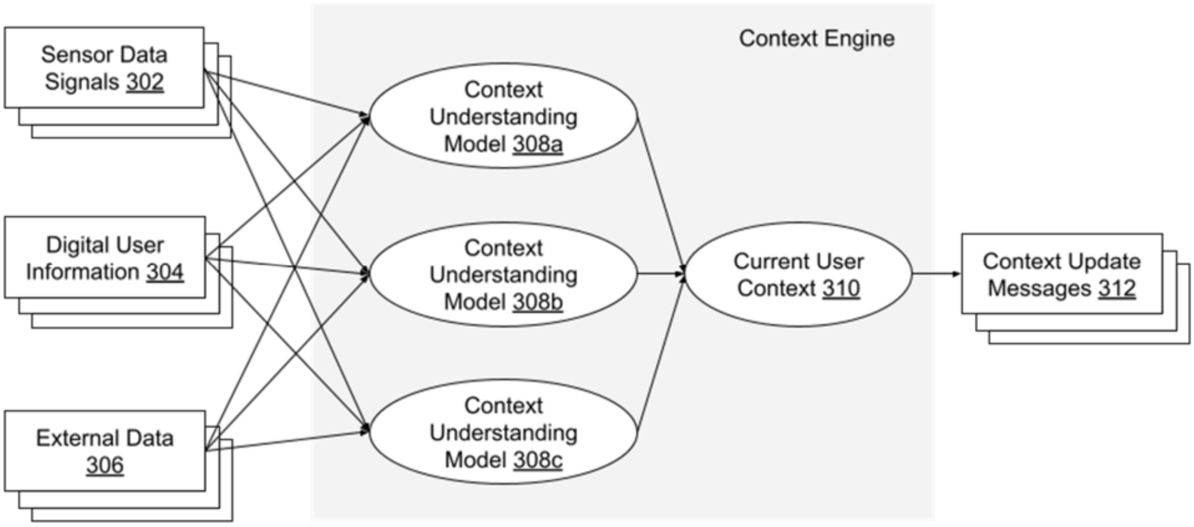

Fig. 3: Components of the context framework

As illustrated in Fig. 3, the described context framework includes the following.

- Sensor inputs (302): Information from individual wearable computing devices relevant for contextual experiences.
- Digital user information (304): Information relating to the user's digital behavior, e.g., preferences; history; content; present digital activities, e.g., viewing a cooking tutorial, playing a workout playlist, checking email, working on a presentation, etc.;
- External data (306): Information relating to external data such as date, time, weather, traffic, etc.
- State management: State management with the hyper-localized wearable computing device input and the remainder of inputs across the user's devices. State management includes the use of context-understanding models (308a-c) to arrive at the current context, or state, of the user (310). Context-understanding models can include machine-learning models, hand-made models, heuristics, or a combination thereof, that have the ability to adapt or learn based on user feedback. The models can operate on a range of

timescales, from immediate to historical. With user permission, the models can optionally be personalized, e.g., specific to the user. In the absence of such permission, the models can draw upon the aggregate statistics of a population.

- Outputs (context update messages) (312): Delivery of contextual experiences, including information about when and on what device or interface content is to be delivered to the user.

Example use cases: The described techniques can enable a variety of use cases. Some example use cases include:

1. Contextual suggestions
    - When the user starts a workout, their watch suggests helpful content like the user's running playlist.
    - Near bedtime, devices help the user wind down with tips based on the user's activities that day.
2. Enabling politeness in devices
    - Earbuds lower the volume of music when the user starts a conversation.
    - The notifications on a watch are muted while the user presents at a meeting.
    - Earbuds pause the user's audiobook when the user falls asleep.
3. Location awareness
    - When the user leaves the house, their podcast transfers from their earbuds to their car.

The context engine, as described herein, accesses and uses sensor data from one or more user devices with specific user permission. Data fusion is carried out in accordance with user-controlled preferences. The determination of context is performed with user permission and the granularity of such determination can be controlled by the user. User data is stored securely only on devices that are permitted by the user (e.g., local devices only, local + cloud, etc.). The use of user data and the analyses that are performed using such data for various contextual interactions is limited to applications that the user enables. The user can restrict permissions for contextual interaction to specific applications. The described features are implemented in compliance with applicable regulations regarding user data (e.g., use of biometric or other identifiable data may be restricted or such data may not be used). The user is provided with clear information about the type of data that may be obtained or utilized, the rate of obtaining such data, the granularity of data, etc. as well as the operations (e.g., sensor fusion, use of context determination ML models, etc.) performed using the data. The user is provided with options to disable context determination and contextual interactions, in which case no data collection/analysis is performed for such purposes.

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 context, actions or activities, 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 a context framework that, with user permission, integrates wearable and stationary sensor inputs and traditional digital context into a larger computing ecosystem to deliver content across a range of proactive ambient computing use cases. Devices and apps register their sensors with a context engine and send periodic data updates to the engine. Using machine learning models, the context engine updates the user context based on sensor and external data, and provides the user context to registered devices and apps, which modify their behavior or surface content based on the user's context.

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