Crowd-Based Ambient Assisted Living to Monitor the Elderly's Health Outdoors

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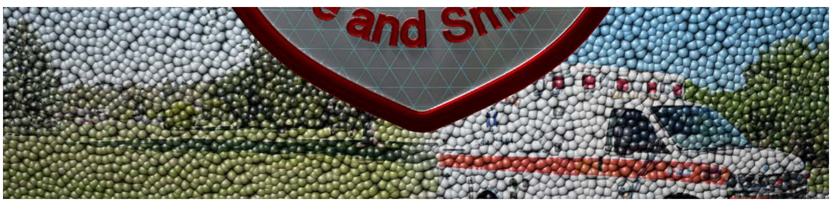
// The SafeNeighborhood approach combines data from multiple sources with collective intelligence. It merges mobile, ambient, and AI technologies with old-fashioned neighborhood ties to create safe outdoor spaces for the elderly. //



THE WORLD POPULATION is aging rapidly. Projections are that people 60 years old or older will outnumber children by 2030 and adolescents and youth by 2050.[1] As the population ages, the need is increasing for policies, systems, and technologies that support healthy aging. Aging leads to gradual physical decay, which increases dependency on others. *Ambient assisted living* (AAL) prolongs people's ability to stay active and independent as they age.[2]

Most AAL research focuses on indoor (home) environments using information from sensors in the environment and on the person.[3] However, many activities occur outside the home environment, causing new safety concerns. For example, even healthy elderly people might get lost, be exposed to excessive heat or cold, fall, become confused, or experience a health risk. Additionally, many AAL solutions require that seniors take action (pressing a button, making a call, and so on), which might not always be possible.

We're exploring AAL techniques in outdoor environments to increase the elderly's independence without them having to interact with technology. Current research in outdoor monitoring relies solely on sensor data.[4] Our approach, which we call *SafeNeigborhood* (SN), crowdsources people in the neighborhood to revise the computer's inferences from contextual and sensor data. So, SN brings the community together to provide a safer environment for the elderly.

The SafeNeighborhood Approach

The SN model is based on four assumptions:

- *Technology*. The elderly carry a mobile or wearable device but might not be able to (or want to) interact with it for self-monitoring.
- *Society*. In a community, neighbors care for each other.

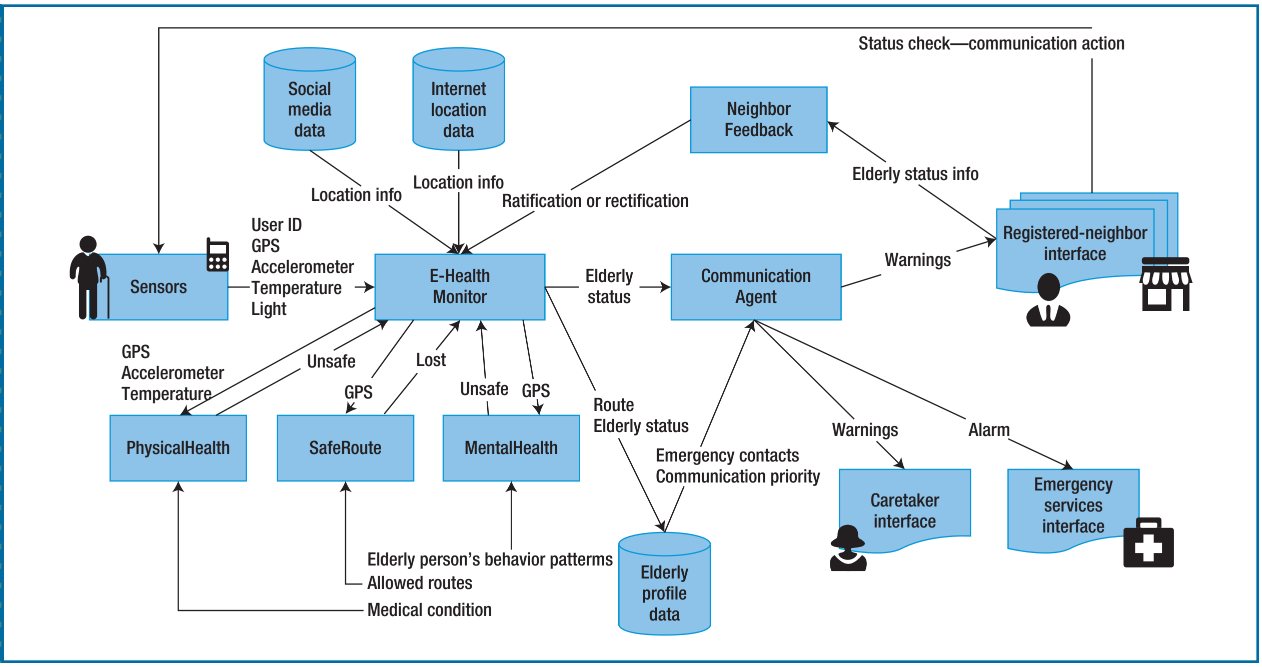


FIGURE 1. The *SafeNeigborhood* (SN) model. SN combines sensor information, data from the web, and community participation to provide a safer environment for the elderly.

- *Communication*. The elderly move slowly, so information needn't be transmitted with high frequency.
- *Collective intelligence*. Given a community with many neighbors, somebody is likely to notice an elderly person at risk and report it.

The SN Model

We implemented SN as a client-server application, using a cloud-based server. Figure 1 illustrates the SN model, emphasizing the information flow among its components. SN contains the following three main modules.

First, the *E-Health Monitor* performs data acquisition and fusion from various sources to determine the elderly person's status. It interacts with three submodules:

- *SafeRoute* detects the elderly person leaving the acceptable location, on the basis of GPS data, the current route, the elderly person's profile, the designated comfort zone, and possible destinations.
- *PhysicalHealth* infers the elderly person's long exposure to hazardous weather, on the basis of online weather information and the time.
- *MentalHealth* identifies when the elderly person is wandering, on the basis of his or her route and movement pattern.

Second, the *Communication Agent* decides whom to contact and what information to send when an anomaly occurs.

Finally, *Neighbor Feedback* aggregates individual neighbors' contributions to revise the diagnosis of the elderly person's condition.

How SN Works

The *elderly interface* (see Figure 2) is a mobile app that captures sensor data from an elderly person's mobile device. The current implementation runs on a cell phone that has the necessary sensors (GPS, an accelerometer, and light and temperature sensors).[5] The interface sends the data to the E-Health Monitor at regular intervals.

The E-Health Monitor retrieves that person's current location, the nearby points of interest, and weather information from the Internet and retrieves a list of geographically close friends from the trusted neighborhood network. A data fusion layer integrates this information, using the JDL (Joint Directors of Laboratories) method.[6] SN stores the elderly person's route as a set of time-stamped GPS coordinates taken at specified time intervals. It also records the temperature and fall detection status.

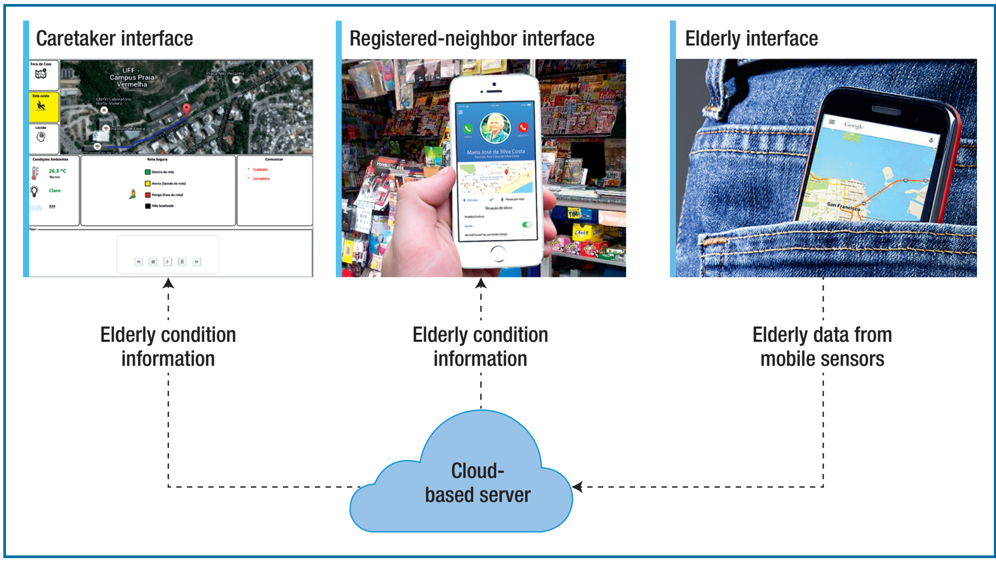


FIGURE 2. The three SN interfaces. There's no computer interaction with the elderly person; his or her mobile device only sends data to the system.

From that data, the E-Health Monitor infers one of five statuses:

- *OK*. The elderly person is safe.
- *Fallen*. The elderly person has fallen down and hasn't gotten back up on his or her own in a given time period.
- *Adverse weather*. The elderly person has been in the sun, rain, heat, or cold longer than a given time period.
- *Wandering*. The elderly person is repeatedly passing by the same place in a short period of time, stopping frequently or zigzagging.
- *Risk of getting lost*. The elderly person is moving away from an acceptable location.

When the E-Health Monitor detects a problem, it prompts the Communication Agent to communicate with the appropriate people (caretakers, relatives, physicians, an ambulance, or neighbors). These participants have different roles with different information access clearance and commands. The Communication Agent continues to send warnings to multiple neighbors until a few of them respond. After the system identifies the neighbors (through a token, mobile-device safety code, or biometrics), it sends them the elderly person's risk information.

Using the *registered-neighbor interface* mobile app (see Figure 2), the neighbors can confirm or correct the information (or ignore the message). The confirmation is based on discrete-time-signal-processing theory.[7] The neighbors' messages are discrete-time signals: 1 (confirmation) or −1 (correction). In either case, there's additional associated information: confirmation of the elderly person's location and status.

The responding neighbors might also approach the elderly person to offer information, help, or engage in conversation until help arrives. Neighbors who are near the elderly person also answer simple yes-or-no questions on their app (for example, "Did you see him or her walk past?" or "Has he or she fallen nearby?"). Their answers enrich the data and help reduce noise in inferences.

The same answers from multiple neighbors helps verify the data. SN uses GPS data to verify that the respondents are actually in the area and near the elderly person. If an emergency call is necessary, the Communication Agent handles it, preventing multiple calls to the same person.

The *caretaker interface* (see Figure 2) provides an easy way for relatives to monitor the elderly person's activities, identifying any unusual behavior or hazardous events. It indicates the elderly person's location and status, the weather conditions, and whether he or she is in an acceptable area. A history viewer shows the elderly person's activities, providing context for any reported event. This interface can run on a mobile device or desktop computer.

Information Access, Privacy, and Safety

Rapidly communicating the elderly person's status is key to guaranteeing timely assistance. However, personal data shouldn't be distributed indiscriminately. Researchers have proposed several solutions to reduce the possibility of personal information falling into the wrong hands in social networks.[8] We adopt a trusted, private, neighborhood-based social network, as in Nextdoor (nextdoor.com) and Goneighbour (www.goneighbour.org).

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In our network, a participant can have one of two types of ties to the elderly person: caretaker or neighbor. During SN setup, before using the SN app, the elderly person or a relative can stipulate who the trusted individuals are and their roles, limiting access to the elderly person's personal information. When a network is constructed, only trusted individuals are linked to any particular elderly person. So, each elderly person has a network of known individuals who will come to his or her assistance when necessary.

Protecting personal data for privacy involves maintaining query, owner, footprint, identity, and location privacy.[9] In our approach, query and owner information are never available. The elderly person's footprint information is available to only relatives or caretakers. His or her identity and location are partially delivered to neighbors when an emergency occurs because they need to identify the elderly person at risk. This information is disclosed willingly, and some privacy will be sacrificed in the name of user safety or assistance. We're expanding our research to deal with these safety concerns.

As people age, they're at risk for many health-related problems. However, many elderly don't wish to give up their independence to stay in a nursing home or be always accompanied by a caretaker. Their communities have the means to ensure their safety and well-being with minimal cost. This community-based approach for assisting the elderly works well for small neighborhoods or regions where people know each other and a sense of community exists. Everyday interaction contributes to this sense of community and is a basis for SN.

Currently, SN works only with healthy people whose senses are declining owing to aging. It doesn't handle severe disabilities such as Alzheimer's disease, blindness, or deafness. It also doesn't track the elderly's vital signs; it aims to infer the elderly's status by observing their interaction with the environment. Undesirable events happen, and fast help is necessary to maximize the chances of a fast recovery.

Our tests showed that fall detection through accelerometer readings quickly drains the mobile device's battery, making the system useless. An alternative is to detect falls by tracking the elderly person's position and checking with the neighbors whether something is wrong when the elderly person has remained stationary for a long time. Most current research doesn't address this important issue.

We took a realistic approach because many cities might not have the necessary infrastructure to support full smart-health solutions.[10] Even in such a futuristic scenario, many false-positive alarms can be prevented by our social layer of neighbor information confirmation. Furthermore, SN's human-to-human interaction can help calm down the elderly in harmful situations.

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