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Crowd-based ambient assisted living to monitor elderly health in outdoor settings

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ABSTRACT: Humanity is getting old fast. By 2050, 30% of mankind will be over 60 years old. Aging gradually compromises people's independence. Ambient Assisted Living (AAL) technologies can help elderly individuals maintain their independence while providing added safety on a daily basis. Multiple sensors monitor seniors' activities to detect situations in which they might need help. Most research in this area has targeted indoor environments, but elderly citizen's outdoors activities are just as important, as many risky situations may present themselves outside of the home environment. In this paper, we present SafeNeighborhood, an AAL system for outdoors environments, which combines data from multiple sources with collective intelligence to tune sensor data. We merged current mobile, ambient and artificial intelligence technologies with old fashion neighborhood ties to create safe spaces outdoors. Initial results indicate the potential use and opens new opportunities for elderly care.

KEYWORDS: Human-centered computing, Handicapped persons/special needs, Healthcare, Elder care, Ambient Assisted Living

Elderly Routines and Independence Decay

Data from a 2015 UN report shows that the world population is aging rapidly. Projections are that older persons (aged 60 years or more) will outnumber children (ages 0-9) by 2030 and adolescents and youth (aged 10-24 years) by 2050 [1]. As the world population ages, the need for policies, systems and technologies to support healthy ageing increases. Ageing leads to gradual sensory decay, which increases dependency on others. Ambient Assisted Living (AAL) prolongs people ability to stay active and independent as they age [2].

Remaining safely independent is a challenge for elders and a source of concern for their families.
During routine outdoor activities, even healthy elders may get lost, be exposed to excessive heat or cold weather, fall, become confused or experience a health-related event. In a friendly environment in which people know and care for each other, the neighborhood would help elders at risk by calling the caretaker, a family member, or even an ambulance. Unfortunately, people are often too busy to notice that a person may need help.

Most AAL research focuses on indoors (home) environments using information from sensors in the environment and on the person [3]. However, many activities are undertaken outside the home environment, causing new safety concerns. Additionally, many AAL solutions require that seniors take action (pressing a button, making a call, etc.), which may not be possible depending on the situation. We are exploring AAL techniques in outdoor environments to safely increase independence, without technology interaction, of older persons.

In the following sections, we describe and discuss the SafeNeigborhood approach, which binds AAL technology, for inferring senior's behavior, with collective intelligence, bringing the community together to provide a safer environment for the elderly.

The SafeNeighborhood approach

The SafeNeighborhood(SN) model is based on four assumptions:

1. technology: elders carry a mobile or a wearable device, but may not be able to interact with it for self-monitoring purposes;
2. social: in a community, neighbors care for each other;
3. communication: elders move at a slow pace, so information need not be transmitted with high frequency; and
4. collective intelligence: given a community with many neighbors, it is very likely that somebody will notice an elder at risk and report it.

Figure 1 illustrates the SN model, emphasizing the information flow among its components. This model was implemented as a client-server application with three interfaces: a mobile interface to capture the elder data, a mobile interface to interact with neighbors and a monitor interface (mobile or not) to interact with relative/caretaker/physician. An app is installed in the mobile device (client), that should be kept with the elder, to send the sensors' information at a configurable frequency, to feed a central system (server). There is no interaction with the elder.

Current implementation runs on a cell phone, as it contains the sensors needed (GPS, accelerometer, light and temperature sensors) for the monitoring task [4]. SN is not monitoring the vital signs, but the interactions between elder and environment. Data concerning the weather and other environmental conditions are obtained from the Internet, given the GPS location. In addition to layers of activity identification and health condition diagnosing, SN broadcasts selected information to vetted registered neighbors, who are close to the elder at risk, to confirm the condition in a crowdsourced style and initiate contact with the elder. Therefore, the interaction will be between humans (neighbor to elder).

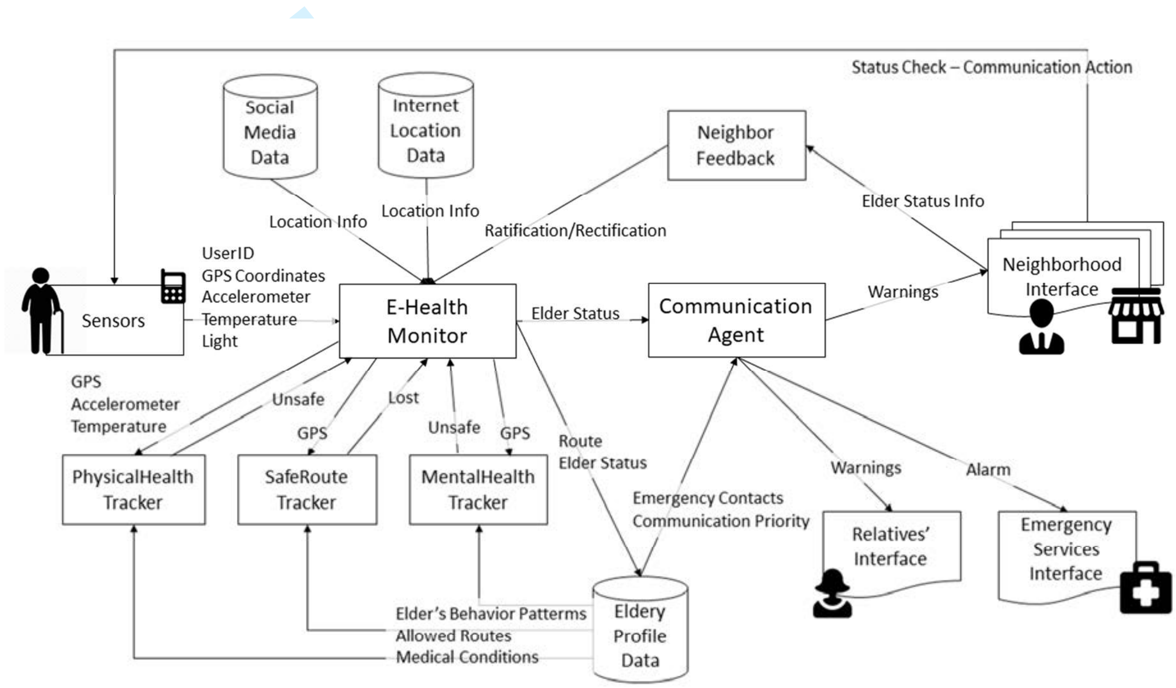

Figure 1. The SafeNeighborhood Model.

Sensor data from the mobile app is sent to the Health Monitor at regular intervals. The Health Monitor receives this data, retrieves current location, surrounding 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 method [5]. The elder's route is stored as a set of time-stamped GPS coordinates taken at specified time intervals. Temperature and fall detection status are also recorded. From these data, the health monitor can infer five possible status:

- Ok: the elder is in safe condition;
- Fallen: the elder fell down and didn't get back up on his/her own in a given time threshold;

- Adverse weather condition: the elder has been in the sun/rain/heat/cold longer than a given time period;
- Wandering behavior: the elder seems lost within the neighborhood (inferred from current path); and
- Risk of getting lost: the elder is moving away from known locations.

Three modules keep watch over the elder: SafeRoute tracker infers the “risk of getting lost” status by taking into account the elder’s current route, profile, designated comfort zone and possible destinations in the current route. Given weather, temperature and luminosity data, the PhysicalHealth tracker infers whether the elder may be affected by local weather conditions. The MentalHealth tracker analyzes routes and movement patterns, looking for frequent stops and zig-zag behavior, which indicate wandering behavior.

Information obtained through sensors and the internet is often unreliable and noisy. Local community members, previously registered and vetted, have an app on their mobile phones that allows them to provide information when prompted. The system shows the data and inferences made and the individual can verify or correct that information. We use discrete-time signal processing theory [6] as a basis for our information confirmation method. The neighbors’ messages are discrete-time signals: either 1 (confirmation) or -1 (correction). In either case, there is an additional associated information: confirmation of the elder location and status.

Whenever the Health Monitor detects a problem, it prompts the Communication Agent to communicate with the appropriate people (caretaker, relative, physician, ambulance or nearby community members). Multiple community members will receive a warning signal that persists until a few neighbors respond to the call. The elder at risk information is delivered upon identification (token, mobile device safety code or biometrics). Upon receiving the detailed message, they may confirm or correct information (or ignore the message), becoming a responder neighbor.

The responders might also approach the elder to offer information, help, or engage in conversation until help arrives. Individuals who are geographically close to the elder answer simple yes/no questions (e.g., “did you see him/her walk past?” or “is he/she fallen nearby?”), and their answers enrich the data and help reduce noise in inferences.

There are four types of devices: mobile devices with sensors to send information from the elder to the system, mobile devices for neighbor to receive/send information from/to the system, desktop/mobile device for relatives/caretakers to monitor the elder and a cloud-based server to run the SN system. Figure 2 illustrates main interfaces for each participant of SN. There is no computer interaction with the elders. Their mobile devices only send data to the system. Different participants such as relative, caretaker and associated neighbor have different roles with different information access clearance and commands.

Figure 2: The three different Apps: Relative/Caretaker app, Neighbor app and Elder app (provides sensor data, no interaction needed), interacting with the cloud-based server.

Each repeat answer from neighbors reinforces previous ones, confirming that the data is correct. GPS data is used to verify that respondents are actually in the area and close to the senior. Should an emergency call be necessary, the communications agent will handle it preventing multiple calls to the same person.

On the relatives' end, a monitor system provides an easy way to monitor the elder's activities, identifying any unusual behavior or hazardous events. It indicates the elder's current position on a map, state (out of the house, fallen, wandering, etc.), weather conditions, if the senior is within his/her safe/known area. There is also a history viewer, which shows the elder's activities, providing context to any reported event.

Information access, privacy and safety

Rapidly communicating the elders' status information is a key aspect for guaranteeing timely assistance. However, personal data should not be distributed indiscriminately. A number of solutions have been proposed to reduce the possibility of personal information falling into the wrong hands when working in social networks [7]. We adopt a trusted, private, neighborhood-based social network, as in Nextdoor [8] and Goneighbor [9].

In our network, participants may have two types of ties with the elder: caretakers and locals (neighbors). Elder users can stipulate who their trusted individuals are and what roles they play in their networks, limiting access to information. When constructing the network, only known/trusted individuals should be linked to any particular elder. In this fashion, each elder will have a network of known individuals who will come to their assistance when necessary.

Protecting personal data for privacy involves maintaining identity, location, query, footprint and owner privacy [10]. In our approach, query and owner information are never available. The elder's footprint information is only available to the relative/caretakers. The elder identity information and location are partially delivered to neighbors when an emergency happens as they need to identify the elder at risk. This information is disclosed willingly, and some privacy will be sacrificed in the name of user safety/assistance. We are currently expanding our research to deal with these safety concerns.

Discussion

As people age, they are at risk for many health-related events. Many seniors however, do not wish to give up their independence to stay in a rest home or be accompanied by a caretaker at all times. The communities in which they live have the means to ensure their safety and well being with minimal cost. This community-based approach for elderly assistance works well for small neighborhoods or regions where people know each other and there is a sense of community. Everyday interaction contributes to this sense of community and is one of the basis for this application.

We are dealing with healthy people, but with impaired senses due to their age. There is no tracking of the elders' vital signs. The objective is to infer the elders' status from observing their interaction with the environment. Undesirable events happen and fast help is necessary to maximize the chances of a fast recovery. On the other hand, individuals with bad intentions are always looking for opportunities to take advantage of fragile people.

To reduce inaccuracy, information generated by the crowd is consolidated to rectify or ratify the elder status. Our tests showed that fall detection via accelerometer readings consumes device battery very quickly, making the system useless. An alternative way to detect falls is by tracking position and checking with the community whether something is wrong when the elder had been stationary for a long time. This is an important issue that most current work doesn't address.

We took a realist approach as many cities may not have the necessary infrastructure to support full smart health solutions [11]. Even in this futuristic scenario, there will be many false positive alarms that can be prevented by our social layer of neighbor information confirmation. Furthermore, our human-to-human interaction is desirable to calm down elders in a risk situation.

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