

# Context-Aware Service Integration for Elderly Care in A Smart Environment

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## Abstract

Advances in healthcare have led to longer life expectancy and an aging population. The cost of caring for the elderly is rising progressively and threatens the economic well-being of many nations around the world. Instead of professional nursing facilities, many elderly people prefer living independently in their own homes. To enable the aging to remain active, this research explores the roles of technology in improving their quality of life while reducing the cost of healthcare to the elderly population. In particular, we propose a multi-agent service framework, called Context-Aware Service Integration System (CASIS), to integrate applications and services. This paper demonstrates several context-aware service scenarios these have been developed on the proposed framework to demonstrate how context technologies and mobile web services can help enhance the quality of care for an elder's daily life.

## Introduction

Advances in healthcare have led to longer life expectancy and an *aging population*. Statistics in Taiwan show that the elderly population (persons 65 years old and over), is expected to rise steadily from 8.5% of the population in 2000 to 9.9% of the population in 2010. In the United States, the elderly population has grown 10-fold within the last century. According to projections by the US Census Bureau, about 1 in 5 Americans would be elderly by the year 2030, compared with about 1 in 8 Americans in 1994. In addition, over 80% of the elderly suffer at least one chronic condition, and 50% have at least two (Administration on Aging (AoA) 2005). Statistics also show that an increasing number of young adults, traditionally the main caregivers for their elders, live apart from family members. In Taiwan, the percentage of elderly living with their children has declined steadily from about 61% in 1992 to 51% in 2002. Similar social trends occur throughout the world, resulting in the progressive rise in the cost of elder care, and threatening the economic well-being of countries worldwide. Many elder people prefer living in their own homes without caretakers, so they can enjoy an *independent* lifestyle.

To enable elders to remain active, this research explores the roles of intelligent sensing, wireless communication,

mobile and ubiquitous computing in healthcare services for the elderly. This paper introduces the Context-Aware Service Integration System (CASIS), which provides context-aware healthcare services to elderly resident in intelligent space, and allows remote caretakers, to closely monitor and attend the elder's well-being anytime, anywhere. Technology eliminates the "geographical distance" between the elders and their caregivers to achieve higher quality elder care.

The smart environment interacts with the elder through a wide variety of appliances for data gathering and information presentation. The environment tracks the location and specific activities of the elder through sensors, such as pressure-sensitive floors, cameras, bio-sensors, and smart furniture. Meanwhile, the elder receives multimedia messages or content through speakers, as well as personal mobile devices. The caregivers may access the elder's health and dietary information through any web-enabled device like a PC or PDA. *Context-aware computing* enables the environment to respond at the right time and the right place, to the elder's needs based on the sensor data collected. The environment is further equipped with integrated controls for convenience, comfort, and safety. The system infers the status of the elder and performs appropriate actions. For example, upon sensing that the elder has fallen asleep, it switches the telephone into voice mail mode. It informs and plays back any incoming messages when the elder wakes up.

This paper, we presents several context-aware services for elder care, and describes the proposed multi-agent service platform. The next section, introduces the enabling technologies, then defines our vision of *context-aware elder care* and introduces the enabling technologies. System architecture and key components are presented following an elder care scenario. Next some important work in elder care and intelligent space is reviewed, and finally, the conclusion of our work is presented.

## Technical Overview

An overview of the context-aware systems, service-oriented architectures and ontology is introduced in this section.

## Context-Aware Systems

During the past years, a number of context-aware systems have been developed to support pervasive computing and

ambient intelligent environments such as Active Badge location system (Want *et al.* 1992), PARCTAB (Schilit, Adams, & Want 1994), and Context Toolkit (Salber, Dey, & Abowd 1999). These systems utilize various sensors and devices to provide location-aware services but lack knowledge sharing and context reasoning.

Typical research dealing with context reasoning is EasyMeeting (Chen *et al.* 2004a)(Chen *et al.* 2004b) and MyCampus e-Wallet (Gandon & Sadeh 2003)(Gandon & Sadeh 2004). EasyMeeting is a prototype of an intelligent meeting room that built on a Context Broker Architecture (CoBrA), an agent-based broker that maintains all the context knowledge represented in RDF triple and utilizes Jena and Jess to support context reasoning. Besides, the policy of SOUPA (Standard Ontology for Ubiquitous and Pervasive Applications) (Chen *et al.* 2004c) is used to control the sharing of users' contextual information. The MyCampus at Carnegie Mellon University has been developed to provide context-aware mobile services for the university's community and an e-Wallet is its key element that supports access control and obfuscation rules for user privacy preferences. Both EasyMeeting and MyCampus deployed context reasoning on their systems but they did not consider the needs of service integration.

## Service Integration

The concept of service integration can be constructed in a service-oriented architecture (SOA) (Natis & Schulte 2003), in which loosely-coupled architecture services communicate with each other. Generally, such communication involves either simple message passing or services which coordinate some activities. Web services technology enables the connection of services. For instance, the World Wide Web Consortium (W3C) defines WS-\* specifications for providing a standard of interoperating between different applications that are running on heterogeneous platforms.

As the environment changes rapidly, we need to define the policies for automatically composing and dynamically building a service integration system which operates agility. W3C proposes WS-Policy (IBM *et al.* 2006) for providing a general purpose model and syntax to describe and communicate the policies of a web service. WS-Policy handles how a particular web service deals with the security, privacy, application priorities, and user account priorities.

## Context Models

In order to know the changes of environment, researchers usually define context models to represent the context information. Typically, time and location are the most well-known context models. Temporal reasoning plays an essential role in context-aware systems. DAML time ontology (Hobbs & Pan 2004) and ISO 8601 date and time formats (W3C Recommendation 2004) are the popular structure and standard. Two important temporal models are point-based and interval-based time model. Traditional time structure is based on a set of points, (Bry, Ries, & Spranger 2005) introduce CaTTs and treat the cultural calendars as interval-based time, and (Ma & Hayes 2006) analyze the temporal interval-based models in a recent literature report.

Many context-aware systems concentrate on location aware services. (Mindswap: Maryland Information and Network Dynamics Lab Semantic Web Agents Project 2004) develops geoOntologies to express basic geographic features such as countries, cities, and relationships between these spatial descriptors. (Open Geospatial Consortium (OGC) 2006) prescribes OpenGIS specifications for GIS data processing and exchange, and OpenCyc Spatial Relations (Cycorp, Inc. 2002) specify the vocabularies of spatial objects and relations.

## Context-Aware Service Integration

We describe why service integration is the trend of the future, and present a sample scenario for elder care, as well as our vision on how technologies can promote a convenient and healthy lifestyle for elders living independently.

### Personal Services

Many people see that the future of Internet access is through the small personal devices, such as PDAs, smart phones, iPods, and Palms. Compared to desktop computers, personal devices are more compact in size, but their CPU and memory are much less powerful. Consequently, the available tools for personal devices are fewer than for the desktop, and most of the desktop applications can not scale well to mobile devices.

In order to circumvent the limitation of personal devices, we deploy a service integration architecture to provide context-aware services. There is a growing collection of context-aware services that users can subscribe to on their personal device and where they can access personal information (*e.g.* current location, health status, and habits). These are subject to privacy preferences. How to let users control the sharing and the use of their contextual information is the problem with which we must deal.

Services are built on different platforms and run on their original computers without need to migrate applications to personal devices. Each service must use exactly the same communication mechanism for communicating with others. Transmission of service requests and the results are sent via wireless networks, such as WiFi. Furthermore, different applications are concerned with different types of knowledge and their corresponding representation model, whereas the messages between services should be understood by each other. Therefore, how to handle such knowledge sharing and maintain the consistency of knowledge is another issue.

### An Elder Care Scenario

Many elderly people have a hard time keeping up with their health regime. Peter aged 69, lives in his home town by himself while his grown children have moved to different locations. Additionally, he is a diabetic and needs to test his blood glucose level several times a day. His physician requests Peter to keep a record of the test results, which are reviewed during the monthly checkups.

Like most elders suffering from chronic diseases, Peter requires routine medication, which may be adjusted periodically by his physician according to Peter's health conditions.

Sometimes, Peter forgets to take his medicine on time. At other times, he gets confused about the prescribed dosage. In order to keep his diabetes under control, the doctor orders Peter to follow a strict diet with meals designed by his dietician. It is also difficult to manage his diet. Peter enjoys *good food*, and considers his diabetic diet overly restrictive. As a result, he tends to make poor food choices. However, there is no way for his dietician and family to monitor Peter's dietary behavior.

Many aspects of elder care can be improved with the help of intelligent space technology, including sensors, context-aware reasoning and web services. Now, let us imagine an updated scenario in which Peter lives alone in a smart house under the care of the Context-Aware Service Integration System (CASIS). His house is equipped with various sensors to monitor and analyze his activities of daily living (ADL). CASIS is deployed to provide personal reminders for health measurements and medication. CASIS also enhances the elder's quality of life by managing his phone messages and information sources like TV programs or news. Even though Peter is living alone, he is not at risk in terms of getting medical assistance. CASIS issues timely alerts so help is only a few minutes away in case of emergency. His doctor and concerned family members are well-informed of his status via web-based interface to CASIS services. In addition, grownup children living afar may monitor the elder's general activities and health condition anytime, anywhere.

## Features

This research explores how technologies can help enhance the quality of care for elders living in a smart environment. The CASIS framework aims to support a happy, healthy and independent lifestyle by providing the following services.

1. *Smart furniture*: The elders can interact with a variety of intelligent interactive objects in a typical home environment. For example, we deploy the *Smart Floor* for non-intrusive location tracking, the *Smart Chair* for logging of vital signs, and the *Smart Table* for monitoring food consumption and nutritional intake.
2. *Context-Aware Information Services*: The elders may receive timely and personalized information services. Using an event-driven calendar, CASIS generates voice reminders, e.g. for taking medicine, when the elder is home, whereas it sends text reminders when the elder is outside of the house.
3. *Healthcare Services*: CASIS serves as the gateway for healthcare professionals to get updated and aggregated bio data on the elder's health conditions. The information enables the doctors to offer timely advice and/or prescriptions that can promote the long-term health of the elder.

## Design of CASIS

Software architecture of CASIS will be described in this section, including the detailed description of each component.

### System Architecture

Figure 1 shows the design of CASIS. A multi-agent platform deploys the context-aware and service integrated architec-

ture on the heterogenous hardware. Every agent in this platform is loosely coupled and only has to concentrate on its main tasks. In our preliminary work, all software components in CASIS are presumed to have prior knowledge necessary to fulfill the needs of elders.

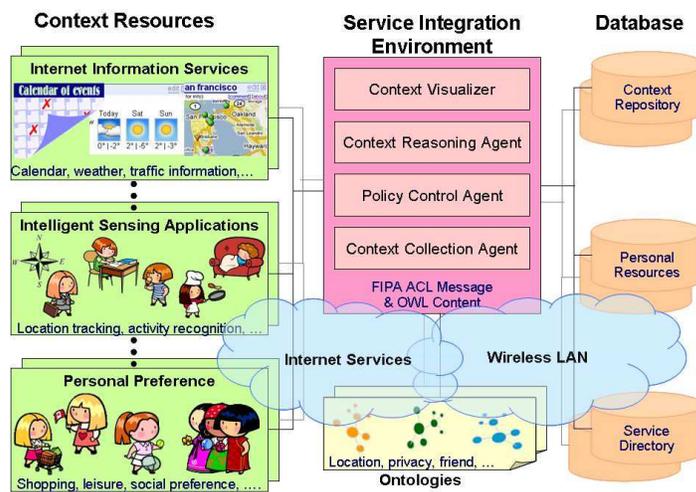


Figure 1: CASIS system architecture

The context of the elder care scenario is the computer sensible environmental information that surrounds Peter. Resources can be the Internet information services, such as weather, calendar, *etc.* Next, many applications deploy intelligent sensors to obtain contextual information, we (Chang *et al.* 2006) utilized RFID and weighing technology to develop a dietary aware dining table. The elder can eat at this Smart Table so that we can easily track what food he consumes and how. When Peter moves around in the house the Smart Floor with pressure sensors can detect his movement (Liau 2005). A prototype of Smart Chair can measure Peter's oxygen level and heart rate when he sits down. Finally, by their preference, elders can specify the access control of their personal information. For example, Peter's child can not get his glucose level history in detail but his doctor has such access right. Context information will be stored in the database shown on the right hand side of Figure 1.

A service integration environment should consist the following four functional components:

**Context Collection Agent** In addition to gathering raw sensing data and transforming it into RDF/XML format before sending messages, Context Collection Agent also collects the personal preference and ontology data.

**Policy Control Agent** This component contains a set of rules and ontologies that relate to user policies, which include access control of personal information, *e.g.* daily schedule and health status.

**Context Reasoning Agent** This agent is an inference engine that reasons from the context knowledge. Ontology inference deduces more context knowledge, and a rule-based reasoning engine can infer the pre-defined rules from the

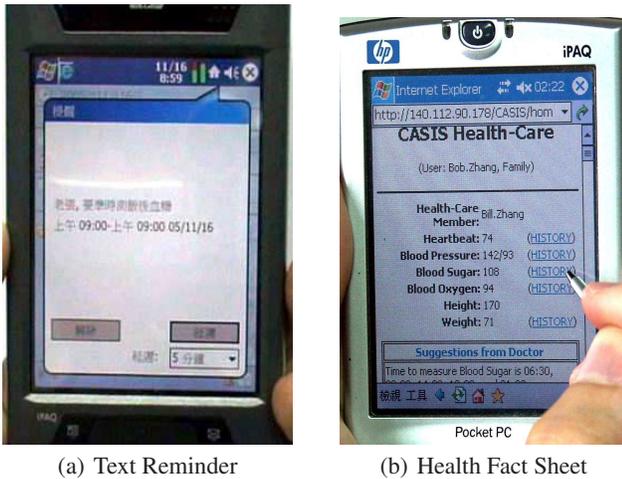


Figure 2: Context-aware and Healthcare Services

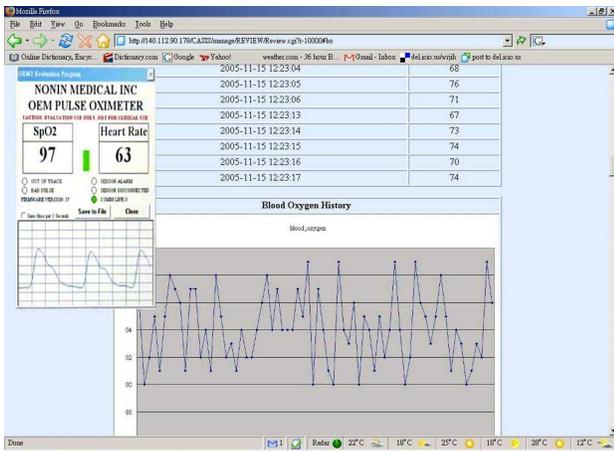


Figure 3: Sensor Data and Vital Signs

current context.

**Context Visualizer** This provides the interface for users to access and query context information. It translates contextual information from Context Repository (see Figure 1) and formats this data according to the pre-defined XSLTs style sheets.

### Illustration

Detailed description and sample screenshots of the scenario will be presented in this section. In order to validate our platform, we design a prototype which uses agent technologies to integrate services and fulfill the elders' needs. As previous section mentions that Peter lives in a smart house. To remind him to take his medication on time, CASIS should send the a message to the right device. Figure 2(a) shows a text message has been sent to the PDA that Peter carries when he is outside. Caregivers and extended family members can remotely check the elder's health status via a web-based interface, shows as in Figure 2(b). Figure 3 displays the sensors data of Smart Chair, which collects Peter's vital

signs when he is sitting.

### Related Work in Elder Care

While the demand for in-home healthcare for the aging population is relatively new, research and development for critical enabling technologies have been gaining tremendous momentum in recent years.

(Pollack 2005) surveys AI technologies that can support elders who are grappling with cognitive decline. Assistive technology can help elders perform necessary daily activities safely, or send an alert to caregivers. Activity monitoring and assurance systems provide alarms and status reports while compensation systems assist elders to accomplish their daily activities. Environment navigation systems easily guide people to find their way. These systems are deployed on modern location tracking technologies, e.g. GPS, bluetooth, and RFID. The AI planning techniques enhance the flexibility of management systems, and temporal reasoning generates reminder plans which satisfy the time constraints of users. Sensor-based monitoring can provide continual assessment of an elder's cognitive status.

House\_n project (Intille 2002) shows an example of a proactive (or preventive) healthcare system using wearable biometric sensors and cameras to detect symptoms of congestive heart failures (CHF) which occur frequently in elders over age 65. When symptoms, such as abnormal changes in weight, blood pressure, sleep patterns, etc., are detected, a proactive healthcare system generates health alerts and recommends remedial changes in lifestyles (e.g., moderate level of exercises) to prevent CHF. LiveNet system from MIT (Sung & Pentland 2004) is a mobile wearable platform consisting of various biometric sensors and a communication radio that can stream bio-signals to the remote caregivers.

The Everyday Computing Lab at Georgia Institute of Technology introduces the *digital family portrait* (DFP) (Mynatt et al. 2001) to provide surrogate social support for aging people who live alone. A *living laboratory* with multi-discipline sensors has been constructed for monitoring the activities of the resident. The sensor data is used to create a digital frame, which is presented to the elder's family living in a remote house. The DFP is designed to be hung on the wall, but it changes daily, reflecting a portion of the elder's life. This can provide the distant family members day-to-day awareness information of their senior parent, and can promote peace of mind for young family members who stay far away from home. Similar to the DFP, researchers at Intel have developed CareNet (Consolvo et al. 2004) which addresses the needs of the Care Network. Such a network represents the care-giving relationship among elder, family, and caregivers.

### Conclusion and Future Work

This paper presented CASIS, a prototype system designed to facilitate independent living of the elderly. The system provides a variety of services for the elder, as well as related services for family, friends, healthcare professionals, and external service providers. Connecting all caring services to-

gether in a service-oriented framework, CASIS coordinates them to provide personalized services. The service-oriented architecture supports loosely coupled system components which cooperate through a clearly defined communication interface.

The current implementation deals with sample elderly care scenarios in order to demonstrate all CASIS functionalities. The system needs to be further enhanced by exploring more complex cases. For example, CASIS should be able to handle conflicting data from multiple different sensors.

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