# 行政院國家科學委員會專題研究計畫　期中進度報告

## 總計畫：iCare：社群化智慧型居家照護(1/3)

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# 行政院國家科學委員會專題研究計畫期中報告

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### 摘要

NSC 計畫"iCare: 社群化智慧型居家照護"第一年度進度報告。在第一年度中，我們針對許多 iCare 系統的重要元件進行設計與原型實作。包括適應性中介軟體，感測器網路，活動感測追蹤以及規則式智慧服務。為了展現我們的技術，我們在 2005 年四月舉辦了 iCare 技術研討會。並且向許多不同領域的學術專家展示我們發展的技術原型，包括工業界的業者與政府代表。在論文發表方面，我們在過去一年內已經發表了超過十五篇論文在頂尖的科學技術期刊與研究論壇上。

### Abstract

This is the 1st year-end progress report for the NSC project "iCare: 社群化智慧型居家照護". During the 1st year, our activities include design and prototype of many of the key system components supporting the iCare system: adaptive middleware, sensor network, activity tracking, and role-based intelligent services. To showcase our technologies, we have organized 2005 iCare technology workshop in April 2005 and demonstrated our developed technology and research prototypes to a variety of academic researchers, industrial practitioners, and government agencies. On the publication side, we have produced over 15 papers in the top technical journals and research forums during the 1st year of this project.

### Background

This is the first year-end report for the main project "iCare: Community-supported Intelligent Care for Successful Aging in Place". The motivation for the iCare project is that advance in healthcare has led to longer life expectancy and so-called aging population trend. The cost of caring for aging population is rising progressively and threatening the economic well-being of the nations around the world. This iCare project aims to explore computing technologies that can help reduce the healthcare cost, and at the same time, offer a high quality, cost-effective, and safe physical and mental healthcare system to take care of our aging population and improve their quality and safety of living.

We would like to summarize our research progress along the following two aspects: (1) *progress report* individual subprojects and their innovations, and (2) *integration efforts* of related subprojects.

### Progress report summary

The iCare project is consisted of four layers, shown in Figure 1. We provide a brief report on the innovation and development efforts for each subproject below. For details, refer to the 1st year-end reports of individual subprojects. In summary, our research progress exceeds most of the objectives outlined in our original proposal.

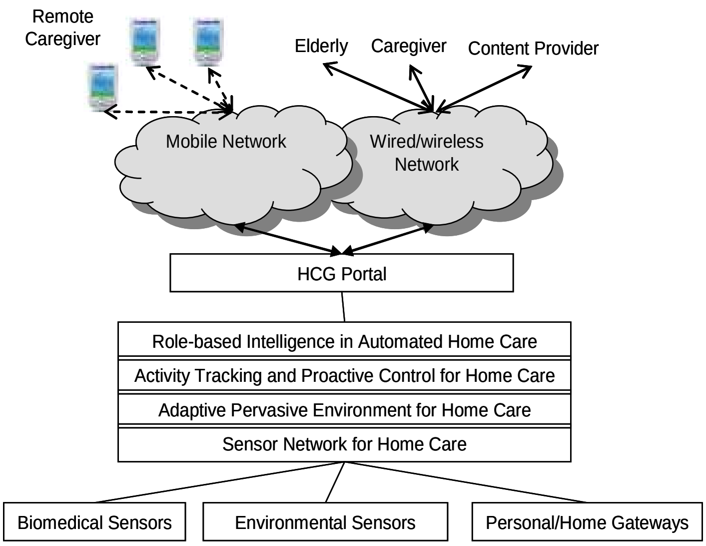


Figure 1: iCare Layered Architecture

### 1 Adaptive middleware

Our innovations and development efforts have focused on four fronts: ***(1a) indoor location middleware*** can track the elder's locations in the indoor environment. We have constructed two types of indoor localization systems and integrate them into a localization middleware. The first type is based a unique infrastructure-less footprint-based method [1][2][3]. This footprint-based indoor location system is built on a pair of traditional Japanese Geta sandals. It can track the indoor position of a user wearing the sandals. It works by measuring and tracking the displacement vectors along a trial of footprints (each displacement vector is formed by drawing a line between each pair of footprints). The position of a user can be calculated by summing up the current and all previous displacement vectors. In comparison to existing indoor location systems, our footprint location system has a unique advantage that it is infrastructure-free. A user simply has to wear the Geta sandals to track his/her locations without any setup or calibration efforts. This makes our footprint method easy for everywhere deployment.

The second type of indoor localization system is Wi-Fi based indoor location systems [4]. We have improved two major technical challenges in current Wi-Fi based location systems: instability in positioning accuracy due to changing environment dynamics, and the need for manual offline calibration during site survey. We have looked at three dynamic environment factors (people, doors, and humidity) that can interfere with radio signals and cause positioning inaccuracy in the Wi-Fi location systems are identified. We have designed and implemented a sensor-assisted adaptation method that employs RFID sensors and environment sensors to adapt the location systems automatically to the changing environment dynamics. The adaptation method performs online calibration to build multiple context-aware radio maps under various environment conditions, selects the radio map that best matches the current environment condition, and uses it for to determine the location.

***(1b) Wearable sensor module*** can monitor the elders' vital signs, such as blood oxygen level, temperature, etc.

***(1c) Adaptive reconfigurable middleware*** [6] can dynamically re-partition an i-care application based whether the serviced elders are mobile (away from home) or in the home environment – in the mobile environment, the application is reconfigured to run on a personal device; whereas in the home environment, the application is repartitioned to run more components on the home gateway.

***(1d) Dietary tracking system*** [5]: we are what we eat. Research continues to confirm that nutrition profoundly influences many chronic illnesses, and it represents one of the most accessible means for prevention and intervention to reduce health risk and promote well-being. Food choice affects our health in many ways. The vast majority of population has chronic illnesses such as heart disease, diabetes, hypertension, dyslipidemia, and obesity in which proper dietary intake and related interventions have been demonstrated to be effective in ameliorating symptoms and improving health. Unlike traditional health care in which professionals assess and weigh each individual's dietary intake, and develop a plan for behavior changes, ubiquitous healthcare technologies provide an opportunity for individuals to quantify and acknowledge their dietary intake in the point of living without intensive labor cost. Such technologies provide a mean for individuals to proactively monitor their food intake and act upon it, leading to a better food selection and sensible eating. We have designed and built a dietary-aware dining table that can track what and how much we eat. To enable automated food tracking, the dining table is augmented with two layers of weighting and RFID sensor surfaces to detect and recognize multiple, concurrent person-object interactions occurring on the table.

**2 Sensor network**

Our innovations and development efforts have focused on two parts. The first part is a new sensor data routing mechanism called ***(2a) magnetic diffusion*** [8][9] that can efficiently and reliability disseminate the sensor data collected in the home care environment. The inspiration comes from the magnetic interactions in the nature. Consider the data sink as a magnet and the data as nails. The data will be attracted towards the sink according to the magnetic field just as the metallic nails being attracted towards the magnet. The magnetic field is established by setting up the proper magnetic charges on the sensor nodes within the range of data sink. The strength of the charge is determined by the hop distance to the sink and the level of resource available at the sink. The data will be propagated based on the magnetic field from low to high magnetically charged nodes. This way of disseminating data results in optimal delay multi-path forwarding. In [8][9], we are able to demonstrate through the simulation results that MD does 1) perform the best in timely delivery of data, 2) achieve high data reliability in the presence of network dynamics, and yet 3) work as energy efficiently as the state of the art mechanisms. We thus conclude that MD is a promising data dissemination solution to the mission-critical applications.

***(2b) Suffix matching algorithm*** [7] enables efficient query and search for sensor data in the environment. Suffix tree (Abbreviate as ST) is a well-known data structure which is extensively used in bio-informatics. The fast construction algorithm allows us to build a suffix tree in linear time. ST is also an efficient search utility when dealing with long strings such as genetic sequence. ST can complete a single attribute-value matching, a search or an insertion in $O(|P|)$ time where $|P|$ represents the length of input sting. For super string search, ST can accomplish a single task in $O(|S|)$ steps if the relation of substring between training strings are figured out during the insertion time. We would like to apply ST on the attribute and predicate matching part of sensor network forwarding systems.

The state of the art is ternary search tree (TST). It is an old but efficient data structure for string matching. In each TST, every node has three children, namely, left-child, middle-child and right-child. For any arbitrary node N, there's a character c which represents a tag for string matching. The left-child contains all substrings that are alphabetically smaller than c, middle-child denotes substrings that start with a character c, and right-child includes all substrings that begin with a character greater than c. TST is an efficient algorithm, it can complete an exact string search in $O(\log(n) + |S|)$ steps where n is the total number of strings in TST and S denote the length of the input string. In the super string search cases. TST can finish the search in O(|S|log(n) + |S|2) steps.

Aside from the above two complex data structures, we also adapt string hash table with a rotation-based hash function as one of our candidate solutions. In the hash table implementation, every input string has a hash value, which indicates the position in the string table. The performance of hash table really depends on the design and adjustment of the hash function. It is generally fast and low memory consumption but still has some weak points. For example, it is hard to implement a substring or super string matching by using merely a hash table while there are already efficient ways for such requirements. The time complexity of a hash table based attribute-value matching with rotation algorithm is O(|S|) steps for hash value calculation and O(1) string comparisons. In the real implementation, we use a simple linked list structure to handle collisions.

We show in [7] the results of comparing the space and time complexity of the three algorithms implemented on embedded Linux-based devices. The results suggest that ST is computationally very efficient and the memory requirement is reasonable for most sensor network applications where the number of data types is in the scale of 100s.

**3 Activity tracking and recognition**

Our innovations and development efforts have focused on the following two parts.

***(3a) Intelligent Reminder System*** [12][13]. By monitoring the person-object interactions and tracking people's indoor locations, we can recognize the elder's activities of daily living and infer high-level safety-related activity context. For example, Aaron turns on a stove in the kitchen (touching the stove knob and a pot) and then walks away for a long time (he may forget to turn off the stove); Barbara opens a window in the morning and later leaves home for an afternoon tea with a friend (she may be in a risk of burglary); Grandpa has a hard time trying to recall if he had taken the medication for controlling his blood pressure. Many seemingly insignificant yet important details in our lives depend heavily on a healthy memory. A simple oversight may result in disastrous consequences. The proposed intelligent reminder system deploys wearable RFID readers (embedded in a glove or a watch) to identify tagged objects that have come in contact with an elder. Meanwhile, a PDA equipped with wireless LAN can track his/her indoor location. We model each elder's activities of daily living (ADLs) based on the context information gleaned from collected sensor data. By utilizing intelligent data analysis and automated reasoning techniques, the system is able to identify unusual and potentially dangerous situations. Our initial experiments have shown that the recognition rate built using them can achieve improved accuracy of 60~100%.

***(3a) multi-agent framework*** [14][15] that can support elder's activity tracking and proactive control, utilizing an event-based activity model, simply RFID sensors, and Wi-Fi location system. Initial results have demonstrated the feasibility of the proposed approach. In a small-scale experiment, the system succeeded in recognizing a small number of activities with 60~100% accuracy. In addition to improve sensing accuracy, we plan to enhance the proposed activity model and probabilistic reasoning methods in order to increase the efficiency and effectiveness of activity tracking.

**4 Role-based intelligent services**

Our innovations and development efforts have focused on two fronts. ***(4a) Taxonomy of iCare e-Services*** [10] categorizes the i-care services into two parts: taking iCare e-Services and giving iCare e-Services. The descriptions of these e-services include:

- Giving iCare e-Services: this represents a set of e-services that engage an elderly person to contribute to individuals or communities, unfolding two sub-categories of e-services (individual-centric and community-centric).
- Taking iCare e-Services: this represents a set of e-services that engage an elderly person to attain a myriad kinds of resources (physical, mental, combined or informative). An example of physical e-services is telemedicine e-services that provide remote medical assistance. Examples of mental e-services include the Home-Movie e-Service and connection-oriented e-services. An example of combined (mental plus physical) e-services is to present to an elderly person therapy entertainment. Informative refers to the e-services aiming at the provision of myriad kinds of information.

***(4b) iCare e-Service Ontology*** [11] discriminates four major concepts (device, home-portal, participant and service). From the concepts of Device and Participant, there will be different hardware and roles involved in the iCare environment. Moreover, Home-Portal is regarded as a smart interface connecting the elderly people with service providers and other kinds of participants. These concepts are further detailed as follows:

- The Service concept is characterized with three high-level attributes (scope, source and type). Scope means the degree of heterogeneity and reachability that a service embodies. Source indicates the resource origins from which an e-service draws upon. Type specifies the forms that an e-service is rendered.
- The Device concept refers to the set of devices (involved in the iCare e-services) that can be divided into two categories (electronic and non-electronic). Electronic means electronic hardware involved in the iCare environment. Non-Electronic indicates the non-electronic equipments around the surroundings.

- The Participant concept is characterized with four attributes (role, relationship, profile and preference). Role indicates the character played by a participant involved in the iCare environment. Relationship means the relationship of a participant to the elderly person. Profile specifies the demographic profile of a participant. Preference specifies the preference of a participant.

The iCare service ontology is the first attempt to delimit quality aging e-services engaging both consumer participation and community involvement. This novel and serviceable ontology is believed to be capable of unfolding the beginning of the industry by soliciting myriad kinds of services characterized by the concepts defined in the ontology.

## Integration Efforts

Our integration efforts within the first year are limited to API definitions between the adjacent layers in Figure 1. We have worked on the following API definitions: (1) relational database interface on the low-level sensor data & the high-level activity data, (2) middleware interface on home gateway, and (3) portal interfaces for role based intelligent services.

We have organized and hosted the *2005 i-care technology workshop*[1] on April 2, 2005. This workshop is co-sponsored by NTU, NCCU, IEEE Computer Society, and ITAP from the Ministry of Economics. We have showcased our developed iCare technology to over 100 audiences of academic researchers, industry practitioners, and government organizations.

## Achievements

On the system side, we have designed, prototyped, and demonstrated many subsystem components in academic conferences, technical talks to potential industrial partners (III, ITRI, IBM, Intel, Quanta computers, etc.), and the 2005 iCare technology workshop, in which we have received positive feedbacks.

On the publication side, we have produced 15 papers in top research forums during the 1st year of this project. Below is the complete list of papers.


[1] Shun-yuan Yeh, Chon-in Wu, Keng-hao Chang, Hao-hua Chu, Jane Yung-jen Hsu, “The GETA Sandals: A Footprint Location Tracking System”, submitted to *Springer/ACM Personal and Ubiquitous Computing (ACM PUC)*, 2005.

[2] Shun-yuan Yeh, Keng-hao Chang, Chon-in Wu, Okuda Kenji, Hao-hua Chu, “GETA Sandals: Walk Away with Localization”, *Adjunct proceedings of the Seventh International Conference on Ubiquitous Computing (ACM UbiComp 2005)*, Tokyo, Japan, September 11, 2005.

[3] Kenji Okuda, Shun-yuan Yeh, Chon-in Wu, Keng-hao Chang, Hao-hua Chu, “The GETA Sandals: A Footprint Location Tracking System”, *Workshop on Location- and Context-Awareness (LoCa 2005), in Cooperation with Pervasive 2005 , (also published as Lecture Notes in Computer Science 3479, Location- and Context-Awareness)*, Munich, Germany, May 2005, pages 120-131.

[4] Yi-chao Chen, Ji-rung Chiang, Hao-hua Chu, Polly Huang, Arvin Wen Tsui, “Sensor-Assisted Wi-Fi Indoor Location System for Adapting to Environmental Dynamics”, *ACM/IEEE International Symposium on Modeling, Analysis and Simulation of Wireless and Mobile Systems (ACM MSWIM 2005)*, Montreal, Quebec, October 2005.

[5] Keng-hao Chang, Shih-yen Liu, Jr-ben Tian, Hao-hua Chu, Cheryl Chen, “Dietary-Aware Dining Table - Tracking What and How Much You Eat”, *Proceedings of Workshop on Smart Object Systems, in conjunction with the Seventh International Conference on Ubiquitous Computing (ACM UbiComp 2005)*, Tokyo, Japan, September 11, 2005.

[6] Chuang-wen You, Hao-hua Chu, “Replicated Client-Server Execution to Overcome Unpredictability in Mobile Environment”, *IEEE 4th Workshop on Applications and Services in Wireless Networks (ASWN)*, Boston, MA, August, 2004.

[7] Jui-Chieh Wu , Hsueh-I Lu, Polly Huang, “Suffix Tree for Fast Sensor Data Forwarding”, Under preparation (2nd draft)

[8] Hsing-Jung Huang, Ting-Hao Chang, Shu-Yu Hu, Polly Huang, “Magnetic Diffusion: Scalability, Reliability, and QoS of Data Dissemination Mechanisms for Wireless Sensor Networks”, Submitted to *Computer Communications, Special Issue on Wireless Sensor Networks: Performance, Reliability, Security, and Beyond*, Summer 2006.

[9] Hsing-Jung Huang; Ting-Hao Chang, Shu-Yu Hu, Polly Huang, “Magnetic Diffusion: Disseminating Mission-Critical Data for Dynamic Sensor Networks”, In the proceedings of the 8th *ACM/IEEE International Symposium on Modeling, Analysis and Simulation of Wireless and Mobile Systems (MSWiM 2005)*, Montreal, Qc. Canada, October 10-13, 2005.

[10] Wei-Lun Chang , Soe-Tsyr Yuan, "Ambient iCare e-Services for Quality Aging : Framework and Roadmap", *7th International IEEE Conference on E-Commerce Technology 2005*, July, 19-22, Munich, Germany

[11] Wei-Lun Chang , I-Chien Lin , "The Framework and Roadmap of Ambient iCare e-Services for Quality Aging", *Fourth International Conference on Mobile Business*, July 11 - 13, 2005, Sydney, Australia.

[12] C. Y. Lin, C. N. Ko, S. Y. Cheng, Jane Y. J. Hsu, and H. H. Chu, “Object Reminder and Safety Alarm”, *The Second International Symposium on Ubiquitous Intelligence and Smart Worlds (UISW2005)*, Nagasaki, Japan, December, 2005. (held in conjunction with the IFIP International Conference on Embedded And Ubiquitous Computing, EUC'2005).

[13] David C. Hsu, M. S. Tsai, T. H. Chang, C. J. Ho, Y. H. Lee, M. C. Wang, and Jane Y. J. Hsu, “iCane - A Partner for the Visual Impaired”, *The Second International Symposium on Ubiquitous Intelligence and Smart Worlds (UISW2005)*, Nagasaki, Japan, December, 2005.


[1] 2005 iCare technology workshop: http://mll.csie.ntu.edu.tw/icare_2005/program.pdf

[14] W. R. Jih, S. Y. Cheng and Jane Y. J. Hsu, "Context-aware access control on pervasive healthcare", *In Proceedings of IEEE EEE'05 Workshop on Mobility, Agents, and Mobile Services (MAM05)*, Hongkong, March, 2005.

[15] J. Y. Hsu and C. Y. Lin, "Event-driven Activity Recognition from Heterogeneous Sensor Data", *In Proceedings of the 2005 CACS Automatic Control Conference*, Tainan, Taiwan, November, 2005.