# 行政院國家科學委員會專題研究計畫 成果報告

## iCare：社群化智慧型居家照護--總計畫：iCare：社群化智慧型居家照護(3/3)
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# 行政院國家科學委員會專題研究計畫成果報告

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# iCare Project: from Pervasive to Persuasive Computing

***Abstract*—Pervasive computing (or ubiquitous computing), as envisioned by Weiser [1], is a grand vision for computing where smart digital technology can seamlessly and invisibly weave into the fabrics of our everyday lives. Currently, two approaches have emerged in designing pervasive computing for digital healthcare applications: the *smart environment* versus the *smart people* approaches. The smart environment approach focuses on *automation* in which digital technology is used to replace people in performing their everyday tasks. On the other hand, the smart people approach emphasizes on *mediation* in which digital technology is not used to replace people's actions, but help people better perform their everyday tasks. Persuasive computing adapts the second design approach. By embedding digital technology into our environments, persuasive computing hopes to modify and shape our everyday behaviors toward smarter, healthier people. In this session, we will share our experiences in the various iCare subprojects on how we come to the path of moving from pervasive to persuasive computing.**

***Keywords* —Pervasive computing, persuasive computing, ubiquitous computing, digital healthcare***

## INTRODUCTION

The iCare research initiative [2] is about embracing and embedding digital technology into our physical living to enhance our everyday experiences at home. Specifically, the iCare research seeks to create intelligent digital technology that can engage and excite people into active participation of desirable physical and mental activities at home that are considered healthy, creative, productive, educational, enjoyable, etc. Our goal is to develop digital technology that empowers people with desirable behaviors, not just supports smart environments. A current research focus is in applying digital technology for healthcare and self-care at home.

The iCare research initiative is an interdisciplinary research effort. Our original team members come from mostly computing background, but have since been extended to cover diverse background in electrical engineering, computer science, information management, occupational therapy, psychology, medicine, and nursing, enabling us to tackle the research challenge of digital living from technical, design, and human aspects.

In this session, we would like to share our experiences through various subprojects conducted in the iCare project, and describes how we have come to the path of moving from pervasive computing to persuasive computing.

## THE ICARE EXPERIENCE

At the start of the iCare project, an object reminder system [3] (video: http://mll.csie.ntu.edu.tw/video/object_tracker.avi) was prototyped to automatically track the whereabouts of objects misplaced by users at home or in an office. The motivation is for the object reminder system to address an everyday frustration in which people often forget where they misplaced things, such as glasses, cell phone, wallet, keys, remote controls, etc., resulting in wasting considerable amount of time looking for these misplaced objects.

To create our object reminder system, we took the smart environment approach and instrumented the environment with ultrasonic positioning sensors. In addition, we created a finger ring RFID antenna that detects when an RFID-tagged object is being held and released from a user’s hand, and a wristband wearable device that combines a small ultrasonic positioning tag, a RFID reader, and a Zigbee radio sensor node called NTU Taroko [7]. To track the location of an object, our system first tracks the location of a user’s hand using the wristband wearable device. Then, our system detects the moment when the user’s hand releases an object, which is also the time when the RFID reader on the wristband wearable device can no longer sense the RFID tag on the hand-released object. The object’s new location is therefore inferred as the position of the hand at the hand-released moment. The object’s new location is then updated on a map shown on a PDA. Fig. 1 shows pictures of our prototype system.

When our object reminder system was shown to human experts, they quickly commented that using this system would likely produce an adverse effect that leads to continuation of a poor habit to misplace things (i.e., not putting things back in the same place). The reason is that with this digital technology, users can always find things whether they put things in/out the same place. This adverse effect can be found in other digital technology. A prominent example is the use of the car navigation system, which may encourage directionless-ness in drivers because drivers are not compelled to the habit of remembering and learning roads and direction while driving. As a result, drivers may become more dependent and reliance on the intelligence of the digital technology rather than on their own intelligence or good habits.

Fig. 1. The iCare RFID-assisted object reminder system. On the top shows the wearable wristband device. In the lower left shows the RFID tag on the object. On the lower right is a map display showing the locations of objects.

## PERVASIVE TO PERSUASIVE COMPUTING

The comment from the human experts about our object reminder system made us think about alternative designs for pervasive computing technology, in which a digital enhanced smart environment motivates people to become smarter (not dumber) with more desirable, healthier behaviors. For the new object reminder, this alternative design also tracks the locations of objects, but only beeps to remind users at the moments when they misplace objects. That is, rather than helping users locate misplaced objects, this alternative design incorporates a behavior modification strategy, in the form of a digital mediation, to motivate a good habit in users such that they will not misplace objects (therefore, preventing misplaced objects from occurring). In other words, we believe that this persuasive approach can be a more effective use of pervasive computing technology in many of our everyday living scenarios.

In our iCare project, we have identified the following three main layers for persuasive technology shown in Fig. 2: (1) sensor infrastructure to sense and monitor human behaviors and their context, (2) activity recognition to interpret human behaviors from low-level sensor data, and (3) intelligent interaction to influence or shape human behaviors. In this conference session, we will describe in more details five different i-Care projects that cover these three layers.

| Interaction Design<br>*(Influence and Shape Human Behaviors)* |
|---|
| Activity Recognition<br>*(Recognize Human Behaviors)* |
| Sensor infrastructure<br>*(Monitor Human Behaviors)* |

Fig. 2. Three layers in Persuasive Technology

## ICARE EXAMPLES OF PERSUASIVE TECHNOLOGIES

To illustrate what we mean by persuasive technology, we describe four iCare subprojects which experiment with adopting persuasive computing technologies for playful behavior modification.

### *Playful tray*

Mealtime behavior is one of the most frequently cited problems by parents of young children [4]. Despite nutritional concerns, spending excessive time to eat a meal affects the participation of children in daily school and family routines, and often contributes to negative parent-child interaction during mealtime. To address this eating behavior issue, we have designed a Playful Tray as a tool to assist occupational therapists and parents in reducing poor eating behavior in young children.

The Playful Tray [5] is embedded with an interactive game played over a weight-sensitive tray surface shown in Fig. 3 (c) and (d). By detecting weight changes of the amount of food consumed, the tray surface can recognize and track the natural eating actions of children in real time. Child eating actions are then used as inputs to play a racing game. Screenshots for the Racing game are shown in Fig. 3 (a) and (b). When starting a meal, a child selects a favorite cartoon character to compete in the Racing game. Upon detecting each eating action, one of the characters would race one step forward to the right. When the child completes the meal, the game ends and the character that has traveled the furthest distance to the right wins the game.

The Playful Tray racing game design is based on combining play-based occupational therapy and persuasive computing. The game design provides internal control, an element of playfulness, to children by given them choices to select a favorite cartoon character to compete in the race. In addition, the pace of the game is also controlled by children's eating behavior. The game design gives a freedom from reality, another element of playfulness, to children by not presenting punishment for not eating or eating too slowly. The game design brings intrinsic motivation by randomly selecting a character to race one step forward after each eating action, which children become motivated to continue playing the game until finishing the meal in order to find out the final result of the race. The Racing game is easily within the performance capability of children by using only their natural eating behaviors as game inputs. In addition, the immediate game response through a character's racing one step forward provides extrinsic feedback to children. Finally, the randomly selected racing character after each eating action satisfies the partial reinforcement principle to encourage repeated performance of child eating actions.

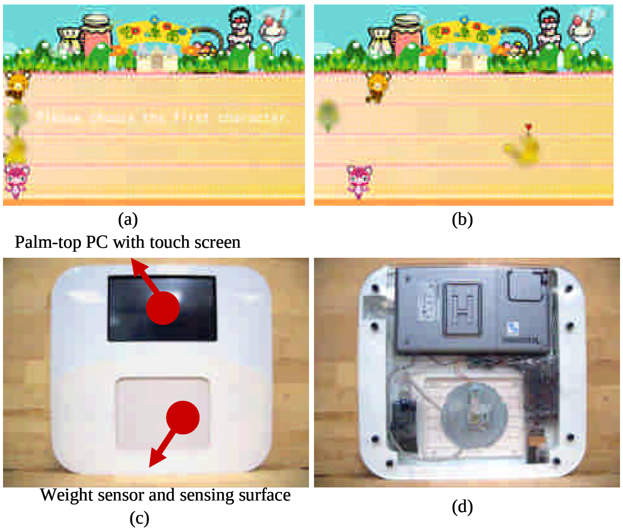


Fig. 3. The Playful Tray prototype: (a) and (b) are screen shots for the Racing game; and (c) and (d) show the tray prototype with a Palm-top PC and weight sensing surface.

*Playful toothbrush*

Proper brushing is essential for cleaning teeth and gums effectively and for maintaining oral hygiene [9]. For many parents, tooth brushing is a required routine for young children before bedtime. However, it is by no means an easy task for parents to get their young children into a habit of brushing their teeth properly and thoroughly. Thus, we have designed and implemented the Playful Toothbrush as a tool to engage young children into active participation and learn proper tooth brushing method as recommended by American Dental Association (ADA) [9].

The Playful Toothbrush [10] incorporates an interactive game played with an augmented toothbrush shown in Fig. 4. The system is consisted of the following components: (1) The toothbrush extension, shown in Fig. 4(b), is coded with different LED marker patterns on its four faces to aid our vision-based motion recognition system. (2) A web camera, shown in Fig. 4(a), is positioned above the child head to capture the top-down view of brushing motions. By analyzing the locations and motions of the LED markers from camera images, our system reconstructs the orientation of the brush extension and rotation of the bristle, and further infers the target group of teeth being brushed. (3) A tooth brushing game, shown in Fig 4(c), takes the child's current physical brushing motions as game inputs to play a game on a LCD display. The game starts with a virtual image of a child's dirty teeth. The goal is for a child to thoroughly clean these virtual dirty teeth using his/her own physical tooth brushing motions as game inputs. For example, while a child is brushing his/her outer left teeth group, it is mapped to cleaning the virtual outer left teeth group of the mirror image on the LCD screen, with visible spots of plaques falling off. Fig. 4(d) and (e) show two game screenshots. When the child finishes cleaning all his/her teeth, the virtual teeth will become completely white accompanying with applause sound.

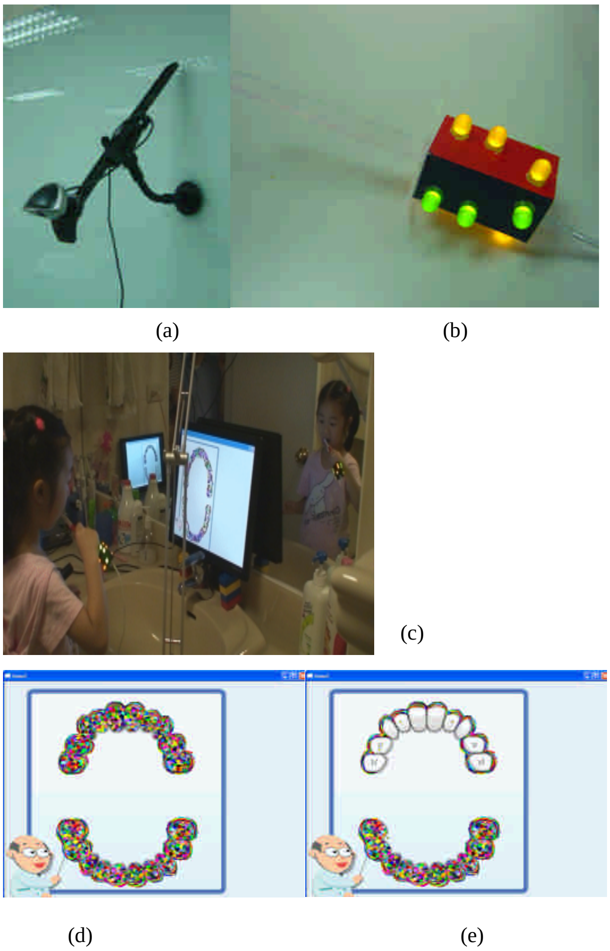


Fig. 4. The Playful Toothbrush prototype: (a) shows a web camera to capture the top-down view of brushing motions; (b) is the toothbrush extension with LED marker patterns; (c) demonstrates a child using our Playful Toothbrush; (d) and (e) are screenshots of the Brushing game.

*Nutrition-aware Cooking Kitchen*

Obesity and overweight are major contributors globally to serious diet-related chronic diseases, including cardiovascular disease, hypertension and stroke, diabetes and others [11]. To prevent obesity and overweight, special care should be taken to maintain the calorie content of every meal within daily requirements. Packaged foods sold in grocery stores have nutritional information including number of calories. However, a recent study has indicated that most people still favor home cooking or cooking meals from scratch [12]; in Europe, 52% and the US, 44% of people prefer scratch cooking. Average family cooks may not know how many calories are in their cooked meals after raw food ingredients are mixed and cooked, or whether these meals are considered healthy and offer a good number of calories for their family members. One of the reasons is that the average family cook cannot easily follow the steps of calculating calories during an intense cooking activity: first they have to estimate accurately the amount (weight) of each food ingredient used (such as oil, meat, vegetables and others), and then they have to look up a food calorie table to calculate the overall number of calories after cooking and mixing several ingredients in a course or a meal.

This study presents a Calorie-aware Kitchen that can provide family cooks with awareness on the number of calories in their home cooked meals, thus help family cooks make healthy meals with the appropriate amount of calories, as recommended by nutritionists.

Fig. 5 depicts our Calorie-aware Kitchen [7]. It is augmented with sensors that track the food ingredients used during cooking, and provides just-in-time digital feedback to raise healthy cooking awareness. For instance, when a user prepares a meal, the kitchen presents calorie information whenever the user performs a cooking action that changes the amount of food ingredients on the kitchen counter or the stove, such as by adding meat, pouring in oil, etc. Given the number of calories of each ingredient, an average family cook can reconsider the amounts of ingredients or the composition of a course, to achieve a good balance between healthy and delicious cooking. The developed kitchen also suggests the recommended number of calories for a meal, based on the Harris-Benedict equation [25], for the entire family. Finally, an element of playfulness lies in a calorie-aware cooking game, which makes cooking more enjoyable.

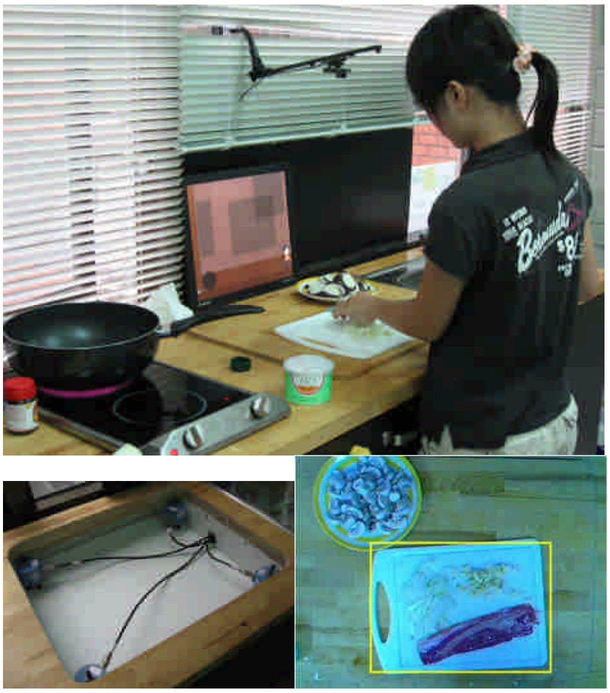

Fig. 5. Calorie-aware Kitchen with calorie tracking and digital feedbacks of nutritional information during cooking process. The bottom left shows weighing sensors deployed under counter, and the bottom right shows the overhead camera to capture images of the counter.

### *Diet-aware Dining Table*

Our dietary habits affect our health in many ways. Research [19] has confirmed that dietary habits are important factors for healthy living and have profound impacts on many chronic illnesses. The vast majority of the population has chronic illnesses such as heart disease, diabetes, hypertension, dyslipidemia, and obesity. A recent Surgeon General Report indicated that approximately 300,000 U.S. deaths are associated with obesity and overweight each year. The total cost attributed to overweight and obesity amounts to $117 billion in 2000. Proper dietary intake and related interventions are effective in ameliorating symptoms and improving health [20].

Nutritious dietary is one of the most accessible means for people to prevent illness and to promote well-being [20]. Unlike traditional healthcare in which professionals assess and weigh one's dietary intake and then develop a plan for behavioral changes, ubiquitous healthcare technologies provide an opportunity for individuals effortlessly to quantify and acknowledge their dietary intake. For example, at home patients face the cumbersome need to record everything they eat, a task which can take a minimum of 15-20 minutes per day [21]. Ubiquitous computing technologies provide a means for individuals to proactively monitor their intake and act upon it, leading to better food selection and more sensible eating.

The diet-aware dining table [18] is a dietary tracker built into an ordinary dining table as shown in Fig. 6. The motivation for creating this table is to influence of our eating behavior. We have designed and implemented a diet-aware dining table that can track what and how much we eat from the table. To enable automated food tracking, the dining table is augmented with two layers of weighing and RFID sensor surfaces. We devise a weight-RFID matching algorithm to detect and distinguish how people eat. To validate our diet-aware dining table, we have performed experiments, including live dining scenarios (afternoon tea and Chinese-style dinner), multiple dining participants, and concurrent activities chosen randomly. Our experimental results have shown encouraging recognition accuracy, around 80%. We believe monitoring the dietary behaviors of individuals potentially contribute to diet-aware healthcare.

## Related work

Many researchers have looked into how pervasive technology can manifest into our living environment to motivate behavioral change. The persuasive mirror [13] aims to motivate a lifestyle change by showing individuals what they may become in the future. If a person has poor lifestyle habits such as excessive eating, smoking, lack of exercise, etc., the mirror will conjecture an unpleasant future-face to persuade lifestyle change. Tooth Tunes [14] is a smart toothbrush designed to motivate the practice of tooth brushing in young children. The toothbrush is embedded with small pressure sensors to recognize brushing activity when the toothbrush is pressed against teeth. Upon the sensors being activated, a two-minute piece of music is played to reinforce children in continuing brushing for at least two minutes. Waterbot [15] is a device installed at a bathroom sink to track the amount of water usage in each wash. The system contains flow sensors to detect the amount of water usage. By showing the current water usage in comparison to the average household water usage, the system encourages behavioral change toward water conservation. Out [16] designed a high-tech doll that resembles a human baby to simulate the difficulty of caring for a baby. The target users are teenagers with the goal being to prevent teen pregnancy. The doll contains an embedded computer that triggers a crying sound at random intervals. To stop the crying, a caregiver must pay immediate attention to the doll by inserting a key into the back of the baby for a specific length of time to simulate a care session. CarCoach [17] is an educational car system that can utilize sensors in a car to detect good or bad driving habits, such as excessive braking, sudden acceleration, the use of signals when turning, etc. Subsequently, CarCoach aims to provide polite, proactive, and considerate feedback to drivers by factoring into their mental state and current road conditions.

Fig. 6. The picture on the left shows the embedded RFID and weighing table surfaces, and the picture on the right shows a dining scenario.

## CONCLUSION AND FUTURE WORK

In the past two years, the NTU iCare Project has been supported by research grants from the National Science Council of Taiwan, the NTU Research Excellence Program, Intel Worldwide Education Foundation, and IBM Taiwan. The iCare 2.0, a three-year research proposal, has been approved by the National Science Council Taiwan to focus on *intelligent* and *playful* user interaction in real-world environments. Some of the ongoing iCare 2.0 projects are described as follows:

### *ADL-aware Home*

ADL-aware Home [22][23], Recognizing patterns of human activities is an important enabling technology for building intelligent systems for assisted cognition. Existing approaches to human activity recognition often focus on mutually exclusive activities. In reality, people routinely carry out multiple concurrent activities. Our approach to activity recognition adopts a variety of probabilistic models to reason about sequential and co-temporal relationships among multiple concurrent human activities from heterogeneous sensor data, both wearable and in the environment. In addition, we apply machine learning techniques to emotion recognition using physiological signals from wireless wearable sensors.

### *CoESM*

CoESM [24] is a collaborative, context-aware experience sampling method to record experience samples of depressed patients. The goal of CoESM is to help a psychologist gain better understanding of their depressed patient's physical and social activity levels. It is developed on a mobile device, such as a cell phone (shown in Fig. 7,) equipped with location (i.e., a GPS receiver) and activity (e.g., an accelerometer) sensors. From this mobile device, CoESM collects experience samples by delivering and prompting questionnaires to patients. Conditions to trigger questionnaires are dynamic and context dependent. This enables an inquiring psychologist to specify conditions matching potential activating events of interests. When a patient completes a questionnaire, CoESM automatically logs a timestamp, and records the current context such as location, physical and social activity level. One of the interesting features of CoESM is collaboration. It enables caregivers (i.e., family and friends) to participate in recording patients' experience after they have had a face-to-face contact with patients. To detect a face-to-face contact, a patient's phone periodically scans any nearby phone via Bluetooth. If a nearby phone belongs to a known participating caregiver, a questionnaire is delivered to the caregiver's phone through SMS messaging.

## PROJECT WEBSITE AND VIDEOS

The iCare project website is located in http://mll.csie.ntu.edu.tw/icare. The video links for the Object Tracker, the Playful Tray, the Playful Toothbrush, the Diet-aware Dining Table, etc., can also be found on the iCare website.

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