iCare Project: Adopting Pervasive and Persuasive Computing for Assisted Cognition

Hao-hua Chu[1,2], Jane Yung-jen Hsu[1,2], Polly Huang[2,3]

Department of Computer Science and Information Engineering[1]
Graduate Institute of Networking and Multimedia[2]
Department of Electrical Engineering[3]
National Taiwan University
{hchu, yjhsu}@csie.ntu.edu.tw, phuang@cc.ee.ntu.edu.tw

1 Introduction

The iCare research initiative at National Taiwan University [1] 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 and enjoyable. Our goal is to develop digital technology that empowers people with desirable behaviors, not just supports smart environments. Our current research focus is on *adopting pervasive and persuasive computing in playful interactions with smart everyday objects in an intelligent environment to assist changing health/self-care behaviors.* Such assistance facilitates independent and healthy living for the elderly, young children, and people with cognitive impairments.

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 backgrounds in occupational therapy, psychology, medicine, and nursing, enabling us to tackle the research challenges of digital living from technical, design, as well as human aspects.

In this white paper, we would like to share our experiences in the NTU iCare research projects. More importantly, we have come to the realization that pervasive and persuasive computing can be an effective means to assist behavior modification, especially for people with cognitive impairments. Not only can smart everyday objects help detect and record user behaviors, but they also provide playful interaction to draw human attention into active participation in desirable behaviors.

2 Core Technology

We have identified the following three technology layers shown in Fig.1: (1) *sensor infrastructure* to sense and monitor the physical or mental context of human behaviors, (2) *activity recognition* to interpret human behaviors from low-level sensor data, and (3) *intelligent interaction* to influence or shape human behaviors.

Interaction Design *(Influence and Shape Human Behaviors)*
Activity Recognition *(Recognize Human Behaviors)*
Sensor infrastructure *(Monitor Human Behaviors)*

Fig. 1. The iCare Technology Stack

3 iCare Experience

In this section, we describe four examples of iCare projects. A complete listing of the NTU iCare projects can be found online at (http://mll.csie.ntu.edu.tw/icare).

- *Playful Tray*: to assist parents and therapists in motivating good meal time behavior for autistic young children.
- *iCane*: to assist path planning and navigation for the visually impaired.
- *Object Reminder*: to assist location tracking and retrieval of objects at home for people with memory impairment.
- *Diet-aware dining table*: to assist dietary control for people with obesity, diabetics or other special dietary needs.

The Playful Tray [2] targets mealtime behavior, one of the most frequently cited problems by parents of young children. 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 and implemented the Playful Tray as a tool to assist occupational therapists and parents in reducing poor eating behavior in young children. The Playful Tray, shown in Fig. 2, is embedded with an interactive game played over a weight-sensitive tray surface, which can recognize and track the natural eating actions of children in real time. Child eating actions are then used as game inputs to play a racing game. This design connects and integrates the fun part (coming from the digital game activity) with the activity of eating. In our pilot user study, we have targeted young children with autism and Asperger's Syndrome. We have found that engaging children in a fun *digital play activity* can be more effective in motivating behavioral changes than using only verbal persuasion. Our pilot user study results have shown that using the Playful Tray reduces mealtime duration by an average of 33%. In addition, children are more focused on self-feeding with the Playful Tray, thereby reducing the occurrences of non-feeding behaviors from about 40% to 20%.

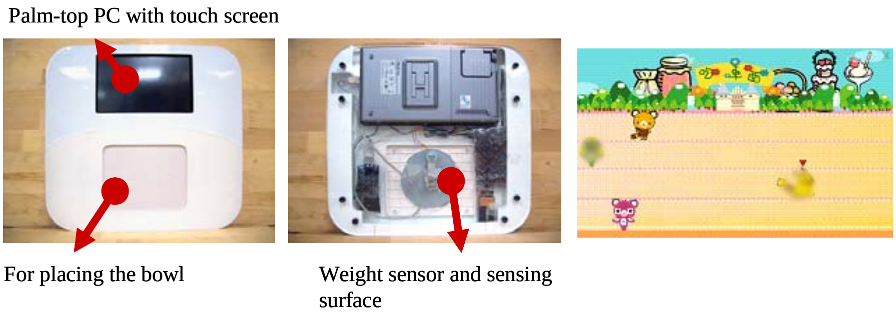

Fig. 2. The two pictures on the left show the top/bottom view of the Playful Tray prototype. The picture on the right captures a screen shot of the Racing Game.

iCane 錯誤! 找不到參照來源。 aims to create a supportive environment with timely and useful information to guide the visually impaired in and around public facilities, such as shopping malls or the MRT stations. Let's assume that location-encoded RFID tags are embedded in the tactile paving. By equipping the standard white cane with an RFID reader, the iCane communicates location or navigation information with the user through his/her PDA with Bluetooth headset.

Fig. 3. In iCane, he standard white cane is equipped with a PDA, an antenna, Bluetooth headset and an RFID reader.

RFID Object Reminder [4][5] can track the whereabouts of objects at home. The motivation is to assist object retrieval for dementia patients who often forget where they place 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 (shown in Fig. 4) that can detect 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 [6]. 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. 4. The object reminder system. On the left shows the wearable wristband device. In the middle shows the RFID tag on the object. On the right is a map display showing the locations of objects.

Diet-aware Dining Table [7] is a dietary tracker built into an ordinary dining table as shown in Fig. 5. 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.

Fig. 5. The picture on the left shows the embedded RFID and weighing table surfaces, and the picture on the right shows a dining scenario.

4 Ongoing Research and Future Plan

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 in this section.

- *Playful Toothbrush*: to assist young children in forming good brushing habits.
- *Nutrition-aware Kitchen*: to assist healthy cooking at home.
- *CoESM*: to assist collaborative experience sampling of interpersonal interaction for depression patients.
- *ADL-aware Home*: to assist daily activities for elderly people living alone.

Playful Toothbrush [8], shown on the left of Fig. 6, is an interactive, persuasive toothbrush to assist parents in motivating and getting their young children into a habit of proper and thorough tooth brushing. Our system includes a vision-based motion tracker that recognizes different tooth brushing motions, and a fun tooth brushing game in which a young child helps a cartoon character clean its dirty virtual teeth by physically brushing his/her own teeth *(video: http://mll.csie.ntu.edu.tw/video/toothbrush_short.mpg)*.

Nutrition-aware Kitchen [9], shown on the right of Fig. 6, is a smart kitchen that can enhance the traditional meal preparation and cooking process by raising awareness of the nutrition facts in food ingredients that go into a meal. The goal is to promote healthy cooking. Our smart kitchen is augmented with sensors to detect cooking activities and provides digital feedbacks to users about nutritional information on the used food ingredients.

Fig. 6. On the left shows the playful lunch, in the middle is the playful toothbrush, and on the right is the smart kitchen.

CoESM [10] 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.

(a) (b) (c) (d)

Fig. 7. CoESM tool: (a) Dopod p800w PDA phone, (b) prompted questionnaire of CoESM in chinese, translating into English is "please indicate to what extent you feel right now", (c) voice recording screenshot, (d) Bluetooth wireless accelerometer from SparkFun.

ADL-aware Home [11][12], 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.

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