CoDine: An Interactive Multi-sensory System for Remote Dining

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ABSTRACT
The pervasiveness of computing has extended into domestic realms, including the dining room. Beyond simply a place to consume food, the dining room is a social hub where family members meet and share experiences. Yet busy lifestyles can make it difficult to spend social time with your family. To provide a new solution for family bonding, this paper presents the CoDine system, a dining table embedded with interactive subsystems that augment and transport the experience of communal family dining to create a sense of coexistence among remote family members. CoDine connects people in different locations through shared dining activities: gesture-based screen interaction, mutual food serving, ambient pictures on an animated tablecloth, and the transportation of edible messages. Rather than focusing on functionality or efficiency, CoDine aims to provide people with an engaging interactive dining experience through enriched multi-sensory communication.

Author Keywords
kitchen, co-dining, interactive media, tangible interface, multisensory, family communication, co-presence.

ACM Classification Keywords
H.5.2 Information interfaces and presentation (e.g., HCI): User Interfaces, Prototyping, User-centered design.
H.5.3 Group and Organization Interfaces: Synchronous interaction, Web-based interaction.

General Terms
Design, Experimentation, Human Factors.

INTRODUCTION
Our world is increasingly populated with a profusion of digital devices designed to assist and automate more human tasks and activities. In addition, the physical world is being increasingly digitally instrumented and strewn with embedded sensor-based and control devices [30]. The kitchen and dining room, places for family cooking and dining, have been a target environment of many ubiquitous computing prototypes that investigate the use of technologies in real-world situations. Previous research to bring technology into the domestic realm has focused on improved efficiency and automation [6, 14, 15].

While technology has arguably made everyday life more convenient, human relationships are going through a transformation as lifestyles are becoming more complex and busier than ever before. The speedy pace of modern life has decreased the opportunities for families to have meals together, especially dual-income families and those who live away from their grandparents. A recent survey showed that families want to eat dinner together, but lack the time or resources to achieve their desires [29]. For at least the past three decades, the ideal in the United States and Western Europe has been for family members to come together for the evening dinner [20]. Unfortunately, advances in technology are dragging people into the digital lifestyle, full of virtual communication, but lacking a sense of warmth and intimacy.

Food, cooking, and kitchens are often associated with an important set of experiences in Western, as well as non-Western cultures [7]. Dinnertime is often a special moment in family life. For many, dinner around the table is a time to reaffirm cultural and familial identity, values, and ideals [29]. Many of us have the memory of eating, talking and laughing when dining together with parents and grandparents. As Rae-Espinoza observed, "The family that eats together stays together" [25].

The social importance of dinnertime inspires our vision: reconnecting family through a computerized dining environment that enhances co-presence, which we call co-dining.

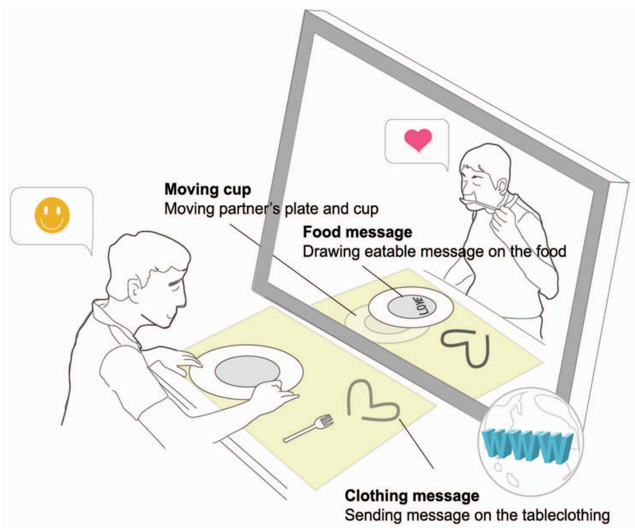

Figure 1. CoDine system scenario.

While families have a strong desire to connect with their loved ones over distance, most communication technologies, like phone and email, fail to provide the same feelings of connectedness that one feels when physically with family members [16]. As an exploration of new modalities to reconnect, the CoDine system is inspired by design research with family members who lived apart, but desired to maintain a close sense of emotional connection. Through a connected dining table, together with expressive and physical interaction, CoDine engages people in shared dining activities and physically embodied affection, to create a sense of intimacy and co-presence between distant family members.

The contribution of this work is the development of the CoDine system, as an extended approach for family eating and socializing. CoDine integrates: (1) an Interaction Screen that enables gesture-based control and interaction in front of the dining table; (2) a Hosting Table that can move the partner's dishes remotely to serve food, showing respect and care; (3) an Ambient Tablecloth that displays animated message on fabric, expressing love and warmth physically; and (4) Food Teleportation to transmit digital messages and self-designed gifts by reproducing them using edible food materials at the remote location. CoDine aims to support a range of mealtime interactions for remote families. Through these mediated communicative activities during mealtime, people can engage in a variety of interactions including creating, sharing and transmitting personalized messages visually or physically through food.

Figure 1 is a conceptual illustration of the co-dining scenario. In this scenario, two persons are enjoying dinner together although physically apart. Using the CoDine system, they can interact through the tangible dinnerware, together with the edible food, to achieve the feeling of a shared dining experience. With integrated sensing and computation, the CoDine system allows one table surface to reflect and respond to the dining activity at a distant location, supporting video conferencing, gesture interaction, food serving, fabric display sharing, and food gifting to facilitate the natural and affective communication between two connected households.

In the rest of the paper, we first describe related projects on intelligent and interactive kitchens to show existing research has not focused on interactive dining. Next, we explain the design approach we applied when designing the system. We then provide a comprehensive description of the system configuration, followed by detailed description of the functionalities for each module, and their integrated application into the whole system. Finally, we conclude by discussing future work on designing interactive media to facilitate effective communication and emotional sharing, taking the advantage of technology embedded in everyday environments.

RELATED WORK

A growing number of domestic, digital and intelligent appliances are appearing, due to the advancement in ubiquitous computing and smart devices. Currently most research has focused on various aspects of the "smart kitchen", for instance to obtain increased functionality, efficiency and security. In parallel, a sizeable body of research has emerged regarding computer-aided systems for interactive cooking, mainly based on numerous displays, webcams, speakers, and sensors [15].

Smart Kitchen

The "smart kitchen" is embedded within the smart house and typically presupposes a digital lifestyle, with the purpose of automating the services and obtaining increased safety and security, comfort, communication and technical management [7].

A number of academic research institutions have been developing robotic and assistive services in the kitchen environment. In the Assistive Kitchen project, researchers developed a service robot that operates autonomously in a sensor-equipped kitchen. The system supports and assists people in their household chores through physical action and monitors health at the same time, using cognitive technical systems [6, 26]. Similarly, the Intelligent Kitchen project uses a human activity recognition system to infer the next action based on previously observed human behaviours. This system also includes an LCD touch panel to display a recipe with pictures and a mobile robot to suggest the next action using voice and gestures [18, 19].

In the U-kitchen system, smart devices communicate with each other and share the context via a kitchen server, including RFID tags in appliances so the system can identify appliances being used, and ubiquitous services which help the user with the grocery management, cooking and give healthy dining advice [4]. The Ambient Kitchen integrates data projectors, cameras, RFID tags and readers, object mounted accelerometers, and under-floor pressure sensing, to construct a supportive environment for food planning, preparation and cooking [21]. Cooking Navi [14], another cooking assistant, aims to help an inexperienced user to cook without failure.

Augmented Reality Kitchen implemented multimedia projections to enrich a conventional kitchen by projecting intuitive displays to reveal the status of tools and surfaces, concentrating on creating interfaces that inform activity without interfering with tasks [17]. Also, researchers have developed nutrition-aware cooking, a kitchen that intelligently senses cooking activities and provides real-time nutritional information to help facilitate healthy cooking [9].

All of this previous research primarily focuses on smart facilities and assistive appliances. While these projects represent one approach to integrating technology into kitchens, we feel this perspective ignores the social element of cooking and dining that could be supported through technology.

Interactive Cooking and Dining

Ubiquitous computing has also been applied to interactive cooking as a social event. The Kitchen Stories project developed a new digital kitchen appliance which allows a user to record, annotate and play back cooking sessions, to make the cooking process explicitly recordable and shareable [31]. The "Kitchen of the Future" is a computer-augmented kitchen environment with embedded video cameras, displays, microphones, switches, sensors and network, to assist the self-recording and replaying of the cooking process, as well as storing interactive multimedia content to provide cooking guidance for others to achieve an enjoyable cooking experience [28]. The Semantic Cookbook [27], automatically captures, and annotates making a recipe using sensors, cameras, and networked kitchen appliances. The captured cooking session can be shared with others.

While some research has focused on dining, remote co-dining, our scenario of interest, has not been explored to the same extent. For example, DinnerWare [11], explored the eating as a medium for computation and aesthetic expression using a dining service electronically equipped to react to the properties of food. Gamelunch [24], a sonically augmented dining table, mapped the usual dining actions like cutting and slicing onto physically-based sound synthesis. Specifically for family dining, the e-Care dining table is designed as an interactive and educational tool for family leisure and educational activity [10]. CU-Later, another communication system that connects two remote dining tables, records and transmits the remote video after a time shift, to allow people to share their conversation while eating despite time difference [32]. However, none of these systems enable the synchronous sharing of dining experience through connected dining table and dining activities.

In contrast, our approach to enable the co-dining experience through physical dining interactions differentiates CoDine from other existing intelligent cooking and dining-based interactive systems. The goal of this research was not to increase the quantity and quality of kitchen-unit activity or event awareness, but rather to support relationship-building activities and extend them to distant dining situations. With CoDine we want to support family bonding, communication, and social togetherness during family dining with remote participants.

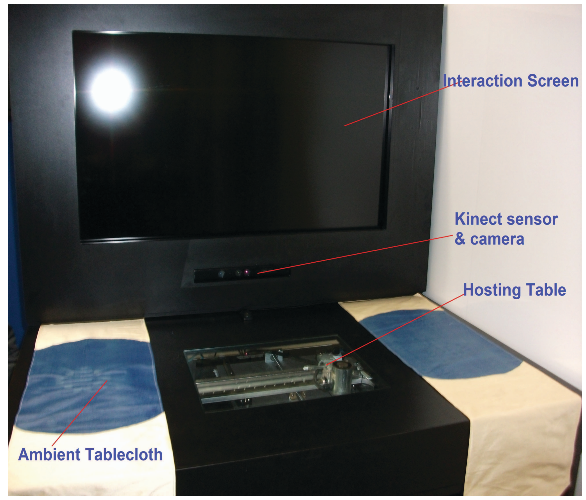

Figure 2. Prototype of CoDine system in dining room.

DESIGN FOCUS: EXPERIENCE SHARING

Technologies for connecting distant family members have typically involved information exchanges and purposeful messaging systems, rather than experience sharing. With the onset of affordable digital media and information and communication devices, communication takes many forms. In face to face situations people are able to use their full range of expression: language, expressions, gestures, and interaction with the artefacts and space. On the contrary, mediated communication has to rely on a more limited range text, sound, image, and video alone or in any combination [5], when face-to-face is not available.

In our system, we concentrate on mediated co-presence, which means "social togetherness" for remote partners [13] during dining. To support co-dining, we were inspired by the concept of co-experience, which is driven by social needs of communication and maintaining relationships. Co-experience takes place as experiences are created together, or shared with others [12].

Interactive technology can play a large role in supporting co-experience, by providing mediated communication channels and the possibility of shared physical activities. This can lead to an increase in feelings of connectedness by providing availability awareness and opportunities for sharing everyday life [8]. In the specific context of family dining, our approach was to better understand what people usually do while dining together from our experience, and extend those activities into remote, but synchronous situations. Moreover, rather than depending heavily on the digital format like video and audio, we believe that interaction with the physical environment can be an important aspect for enriched and multi-sensory communication, which might contribute to the feeling of co-presence.

Based on these principles, we designed a dynamic and interactive environment that draws on and learns from the rich cultural routines of family dinner, and above all, focuses on the human experience. We brainstormed several social activ-

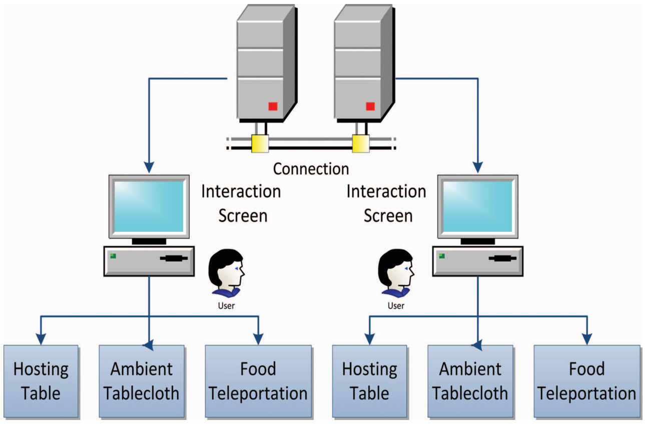

Figure 3. System configuration of CoDine system.

Figure 4. Gesture Interaction with screen to choose icons.

Subset module	Icon	Scenario Functionality	System Action in remote location
Hosting Table		Serving soup	Bowl with soup moves automatically to user
		Serving rice	Bowl with rice moves automatically to user
		Serving Pickles	Bowl with pickles moves automatically to user
Ambient Tablecloth		Expressing Love	Animated heart shape appears on tablecloth
		Expressing Happiness	Animated smiling face appears on tablecloth
		Expressing excitement	Animated exclamation mark appears on tablecloth
Food Teleportation		Sending food message	Food-made message "LOVE" printed on toast

Figure 5. Dining activities the user can select.

ities around the dining table to facilitate synchronous interactions, as shown in Figure 1. Beyond video conferencing, we included activities like serving food, expressing emotions, sending messages, and integrated them into the CoDine system in a tangible and shared manner. By augmenting the dining table, tablecloth and dinnerware with computerized devices, we model the multi-sensory dining experience with embodied extensions of communication, supporting the enhanced sense of engagement and co-existence. Figure 2 shows the actual set up of the CoDine system.

CODINE SYSTEM CONFIGURATION

As explained in Figure 3, the CoDine system consists of four modules. The Interaction Screen, embedded with Microsoft Kinect sensor [1] and camera, works as the hub of the system, enabling the real-time interaction between the remote users. The three activity modules, the Hosting Table, Ambient Tablecloth and Food Teleportation module, are connected with and controlled by the Interaction Screen wirelessly through Bluetooth. When people are dining at the table, their images, together with the dining table surface, are displayed on the screen to achieve normal video conferencing. To initiate any remote physical interaction, people move their hands to choose icons on the screen. Figure 4 shows the gesture interaction with the screen to choose different icons and Figure 5 shows the list of possible dining activities. CoDine tracks the user's hand movement and transmits the icon chosen across the internet to the paired table at the remote location. This triggers the corresponding module of the system on the other side to serve food, to display pattern on tablecloth, or create edible food. Compared with pure video and audio communication, this system provides a wider range for affective expression and interaction. It is through these shared physical messages and social activities that people engage themselves into the shared dining experience, in a reciprocal fashion.

CODINE SYSTEM DESCRIPTION AND IMPLEMENTATION

In this section, we will go through the detailed design and implementation of each module, and explain how they integrate together to achieve the co-presence dining experience.

Hosting Table

One of the shared dining activities in the CoDine system is serving dishes using the Hosting Table module. In many Asian cultures, serving food is considered as an important aspect of the dining etiquette, to show respect, love and intimacy to family members and guests as well. Before the dinner starts, the younger people show their respect and gratitude to the elderly by offering a choice morsel from their bowls. This tradition has been part of everyday activities in our culture, something that we regularly and unconsciously engage in. However, fewer and fewer of the younger generation are aware of this practice as a result of the decreased opportunity for them to dine together with their parents or grandparents. Using this Hosting Table, we aim to bring back the rituals and routines of family dining, even when people are unable to share the same dining table.

To support remote food serving, we designed a remote moving mechanism and embedded it into the normal dining table. The mechanism applies the basic principle of magnetic attraction, combined with two-axis linear movement. Permanent magnets are attached on the bottom of the dishes, including bowls and plates. By controlling the movement of electro-magnet component underneath, we can control the movement of dinnerware on the table. We chose to use magnets because they are simple to implement, easy to control,

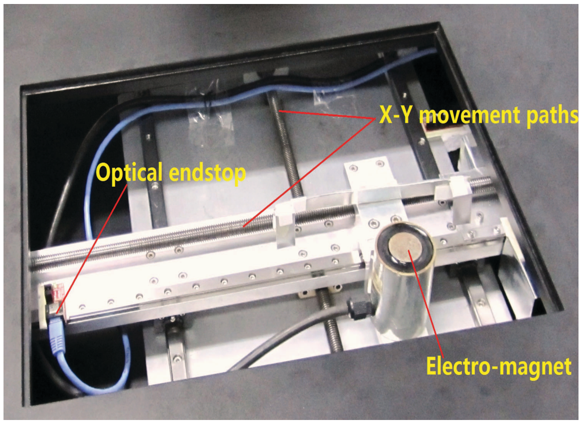

Figure 6. Mechanism of Hosting Table.

and require no wires. When the master controller receives the activation signal, the motors and magnets are activated accordingly to execute the remote moving of dishes on the table surface.

The structure under the table is essentially an electromagnet component installed on an x-y plotter structure (Figure 6). Both axes have two optical limit switches for safety reasons, also for initial position recognition. The movements of motors, activation of electromagnets and wireless communication with the screen are controlled by an 8-bit microcontroller from the master board, embedded with a Bluetooth module.

The Hosting Table, installed as part of the dining table, is integrated with visual interface through Bluetooth protocol, achieving a user-friendly interactive experience based on gesture. For the prototype, it is designed to serve three different dishes. At the beginning, three bowls with different food are put along the farther side of the table, and the electro-magnet in its initial position. When user on the other side selects one of the dish icons from the screen, let's say, serving the rice dish on their partner's table, the electro-magnet will move directly to the position of that dish, activate the magnet, and drag the rice smoothly towards the user on the table surface. Figure 7 shows the actual dish serving after the user selected the serving rice icon.

In the current implementation, the electromagnet component attached to the Hosting Table is designed to move smoothly in x-y dimensions, with a range of 300mm and 400mm respectively. For the purpose of dishes serving, the speed and smoothness of movement are key factors to simulate the natural feeling. Many experiments were conducted on different surfaces, matched with the suitable magnet force and moving speed. A glass surface was finally used to reduce the friction and avoid wiggling effect. To keep the balance between the speed and the natural sense, we set the speed to 16mm/sec in both x and y dimensions, which means that the dish can be served to the user in about 15 seconds.

Compared to interacting in a virtual environment, we believe these physical movements of plates or cups physically on dining table convey more delicate human emotions and stronger feeling of warmth, which contributes to the enhanced sense of co-presence when user take the served dish from their remote dining partner, even though they do not share the same physical dining table.

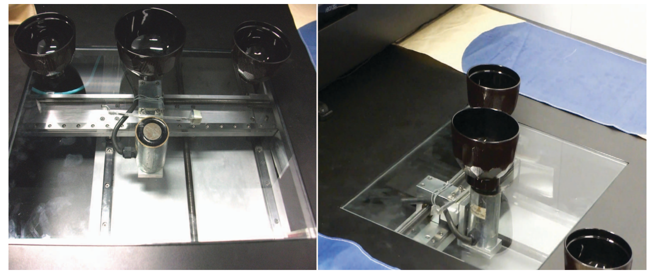

Figure 7. Actual result of hosting table: serving dishes remotely.

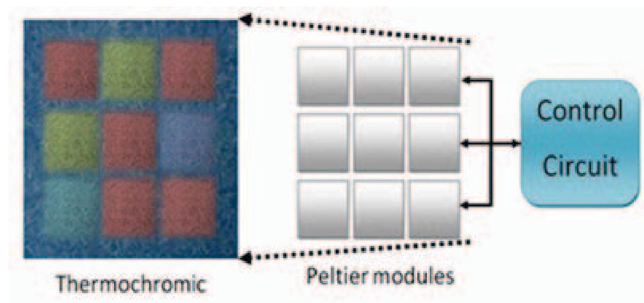

Figure 8. Basic mechanism for the fabric display.

Ambient Tablecloth

The Ambient Tablecloth extends the remote co-dining experience to another component of the dining table, the tablecloth. By introducing the dynamically colour-changing and interactive tablecloth, CoDine further enhances the communication experience around the dining table.

The tablecloth is implemented to display various slow-rate animations through controlled colour changing on fabric. The special-designed tablecloth is placed on top of the dining table, to display different patterns triggered by the messages from the interaction process. We use a non-emissive display technology that can display images on the fabric, while avoiding the effect of unnatural displays on the tabletop.

To achieve this functionality, we are currently using thermo chromic inks combined with Peltier semiconductor elements [22]. The basic structure is depicted in Figure 8. Our tablecloth combines Peltier semiconductor modules and thermo chromic leuco dye ink technologies using a closed loop control system, employing a PI (proportional, integral) controller in order to accurately control the colour. As thermo chromic inks are thermally actuated to change colour, we chose the Peltier semiconductor modules due to its rapid thermal actuation capabilities within a wide range of temperatures. The current inks actuate at 32 degrees (colourless) and regain the original colour of brown at 24 degrees. In addition, Peltier

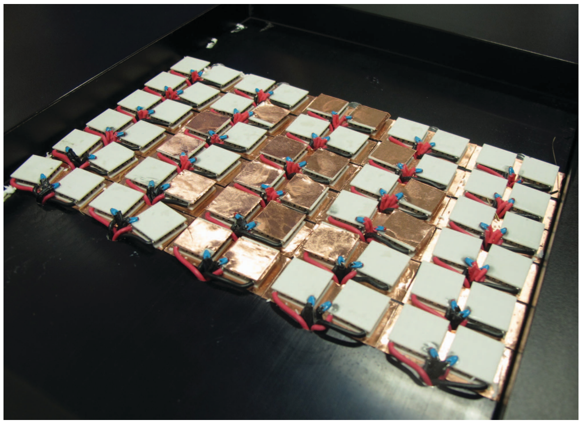

Figure 9. Matrix arrangement of Peltiers for the tablecloth display.

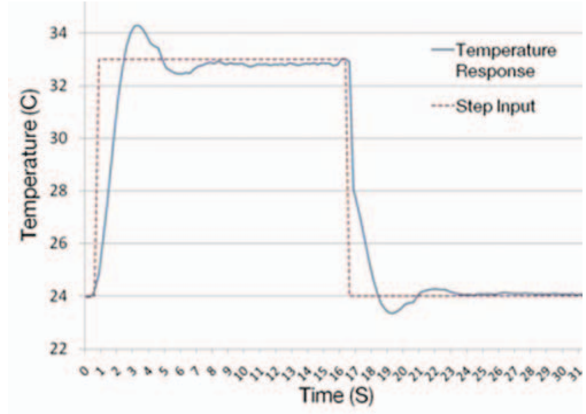

Figure 10. Transient response of one Peltier element.

elements can reverse their function from heating to cooling or vice versa by reversing the polarity of the supply voltage. This allows both heating and cooling of the fabric (a screen printed with thermo chromic ink) dynamically, to achieve a subtle and fast animation effect. This is an advantage compared to most current technologies using thermo chromic inks which only include a heating function. Without a cooling function, cooling must be done naturally, slowing down the bi-directional colour change process and preventing the bi-directional animations of the fabric possible with our approach.

In the current implementation, a pixel display mechanism is applied to achieve accurate display of various patterns. As shown in Figure 9, 60 Peltier modules (1.5cmx1.5cm each) are arranged in a 6x10 pixel display pattern, and the whole display is 20cmx12cm. Fifteen control circuits with each circuit individually controlling four Peltiers are connected to a master controller using I2C protocol. Each controller uses a single microcontroller with the internal oscillator running at 8MHz. Four PWM (Pulse-width modulation) signals are generated using internal timer interrupts at 100Hz. The duty cycle of each PWM signal is controlled by the PID control (proportional, integral, derivative) module implemented in the microcontroller with the four temperature feedbacks. In this way each of the four Peltiers is accurately controlled for temperature using a single controller circuit. The master controller connects to the screen interface wirelessly using the Bluetooth. Once the display patterns are received, the master controller issues commands to each of the control circuits to turn on or off one or one set of Peltiers according to the specific pattern.

The quality of response for Peltier element is quite essential to achieve animated display and pattern changing accurately. Figure 10 depicts the transient response of a single Peltier element. The rest of the Peltiers in the arrangement behave similarly. As observed, the rise time of the system is approximately 1.5s (to go from an ambient temperature of 25 degrees to 32 degrees). In addition, the cooling time of the system also takes approximately 1.5s which is an important characteristic for allowing subtle bidirectional animations on fabric. Some of the resulting patterns are as shown in the Figure 11.

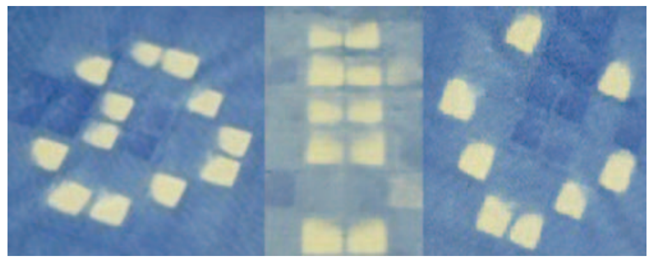

Figure 11. Different pattern display on Ambient Tablecloth:(a) Heart pattern (b) Exclamation mark (c) Smiley.

This ambient tablecloth provides another channel for information sharing and emotion expression between family members in dining situations. It allows users to convey their particular messages in an animated, but tangible way. We feel receiving an animated display on your tablecloth would be surprising and pleasant, and stimulate an enhanced feeling of co-presence beyond receiving plain text or words.

Food Teleportation

Dinner cannot exist without food, of course. The Food Teleportation module is inspired by the importance of food in the kitchen and dining context, and its symbolic character for social bonds. Besides dishes and tablecloth, we believe edible food can also be an affective medium to enhance the emotional connectedness for remote families. Although it is almost effortless to send Short Message Service (SMS), photos or digital gift, these intangible messages miss out the physical and emotional sense of care. Instead, imagine receiving an edible “Hello” from your remote family members during dinner. Food Teleportation achieves this by reproducing the digital greetings (i.e. messages and gift) using edible food materials, which makes tangible the digital messages, creating personalized greetings in edible format.

To transport food, people select the Food Teleportation icon on the Interaction Screen . The user’s selection triggers the remote food teleportation module, and prints out a digital

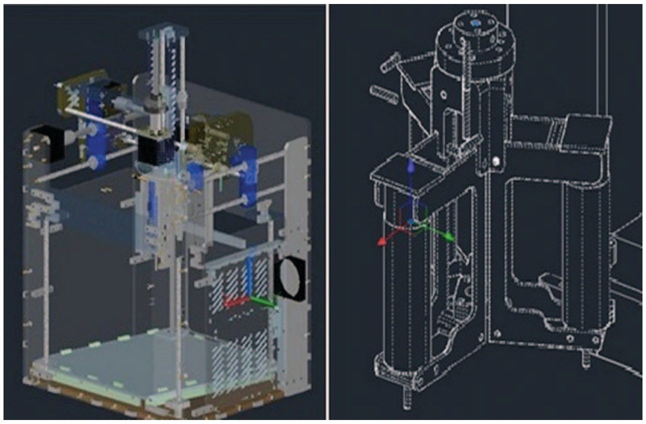

Figure 12. Structure assembly:(a) The whole subsystem (b) Food deposition component.

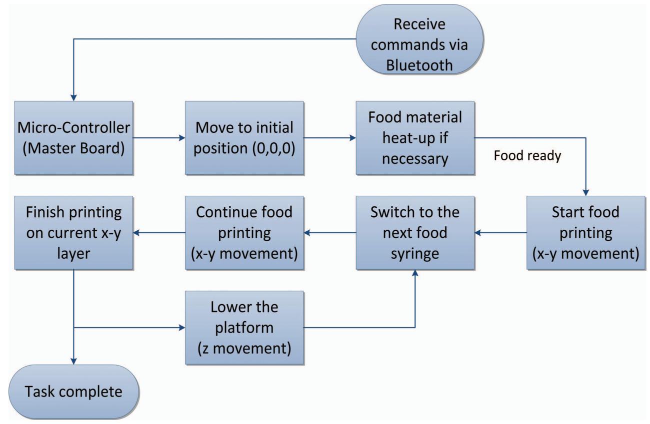

Figure 13. Flowchart of the food teleportation subsystem.

message in edible food synchronously. This message-embedded food is received by loved ones as a unique gift, showing greetings and care physically. Compared with plain text, or digital message like SMS or twitter, transmission through organic food can convey a stronger sense of presence it is more than simply saying "I love you" or "I miss you", it is a physical embodiment of care and affection of one person to others [23], not only visually, but also with smell and taste.

Although currently selecting the Food Transportation icon sends a single message, "LOVE", the Food Transportation subsystem is designed to craft with multiple food materials, not only to make the food message colourful visually and more tasty, but also enable the creation of contextual messages with changed color, smell and flavor, to represent different emotions or feelings. We have experimented with different kinds of food such as chocolate cream (pure black chocolate, white chocolate and milk chocolate), sugar-water mixture, Kaya jam, peanut cream, etc. We also included the most important staple food for Asian households, rice. Food here is the multisensory medium for family communication, and each flavour can be translated into a corresponding emotional state or special experience from one's memory. This flavour-changed eating experience of food gift acts as an intuitive and meaningful way for emotional expression.

Structure Description

The mechanical structure of the subsystem contains two main parts: (Figure 12)

1. 3-axis mechanical structure, with robotic carriage.

2. Food depositing component with 3 syringes .

The mechanical structure is a custom-built 3-axis model of Cartesian X, Y, and Z type. Essentially, the model is designed to use 3-degree freedom robotic carriage to move the food depositing component along the x and y axis and the platform up and down to form z coordinate of the system. The accurate and smooth movement of each axis is achieved through lead-screw coupling powered by step motor, controlled by microchip PIC32MX340F256H from the master board.

The food depositing component is designed exclusively to enable food heating, extrusion and material change while moved by the robotic carriage. A flexible heater can be attached around the syringe and connected with the master board, to heat up the food material that needs to be liquefied before been dispensed. Also, in order to know the exact volume of food material at each beginning of a new material, tiny limit switches are installed under the pushing pad and connected to the master board for position sensing.

This mechanism, connected with the CoDine system, will allow users to reproduce personal digital messages in a remote location using normal food and present to their preferred recipients physically. After receiving the user's chosen message from the interaction, the coordination of the starting point and the motion path for the pattern are interpreted and sent to the food teleportation module on the other side, to be re-produced layer by layer. When finishing crafting the top layer, the platform will move down a certain distance to continue with the next layer. Through this layer-by-layer printing, a 3-dimensional food message or tiny gift could be constructed. Figure 13 illustrates the working flow of the Food Teleportation mechanism.

In building the Food Transportation prototype we had to consider a range of issues. For the mechanical design, we experimented with the diameter of syringe pinhead, coordinate speed of the 3-axis moving motors with piston pushing motor, and the distance between food platform and food droplet, etc. We also had to consider the characteristics of the food to achieve accurate crafting, for example the viscosity and density of different foods at different temperatures.

In our prototype, we experimented with different food materials iteratively to improve the accuracy and resolution, without sacrificing crafting speed. Initially, the message of "LOVE" was crafted with Kaya sauce. With the finalized parameters regarding the mechanical issues, the mechanism crafts with the speed of 5mm/s - 7.2mm/s, taking about 3

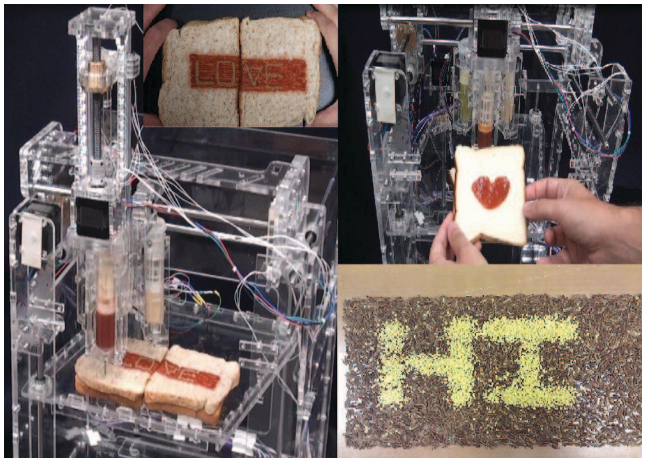

Figure 14. Actual result of food teleportation module.

Figure 15. Photo showing user interacts with the integrated system.

minutes to craft the "LOVE" message, and achieves resolution of 1-2mm. We then implemented multiple-layer printing with changed materials, and composed the heart-shape image using ketchup. Rice is also implemented to configure the "HI" character. Figure 14 shows some of the outcomes from the experiments. We have also experimented with melted chocolate which achieved high resolution for food crafting, but have not yet attached the heating feature to the syringe.

Integrated into the CoDine system, people can achieve affective message transmission during dinner, either by printing the chocolate-made message on a piece of toast located in their grandparents' kitchen, or teleport a muffin with different food materials in each layer to express their complicate and indescribable feeling, or sending a message using different natural colored rice. The richness of the message content was much increased with the inclusion of other senses, like colour, image, even smell and taste, not only because they provide a richer, multisensory description of reality, but because the elements together provided more possibilities for interpretation: emotion, mood and humour [5]. We believe the transmission of physical and multi-sensory message is quite promising to contribute to the feeling of co-presence for remote family members.

Interaction Screen

The Interactive Screen integrates these three activities seamlessly to achieve intuitive interaction experience. It is designed to allow the user easily select the activities he/she wanted to perform while dining. Figure 5 showed the dining activities implemented in the CoDine prototype. Using hand gestures towards the Interaction Screen, people can choose to serve dish, display a fancy pattern on tablecloth, or send edible greetings.

Several interaction methods were considered, including a touch screen and buttons. As the screen is about 1m away from the user, the distance makes the use of a touch screen inappropriate. In addition, the table is to be used for dining purpose, so placing buttons on the table is not user-friendly either, since the user may press the buttons accidentally. Hiding the buttons at the bottom or on the side of the table would make it difficult for the user to see and select the buttons. After comparison, we decided that the most natural interaction in this scenario was to use gesture recognition together with the on-screen display, so that the user can select an action using simple and natural gestures.

The Interactive Screen module includes a Kinect sensor bar and gesture-based on-screen menu selection. One RGB camera inside the Kinect sensor supports traditional video conferencing, allowing the user to see his/her remote dining partner and the partner's dining table. It captures image at 8-bit VGA resolution (640 x 480) at 30 Hz. The stereoscopic 3D camera embedded into Kinect is used to capture and compute the depth of the current frame image. A gesture-based menu selection allows the user to easily select and perform the actions on the remote side. The signals received from tracking the user are transmitted to the remote location, triggering the corresponding subsystem through Bluetooth, which supports food serving, ambient tablecloth display and food messaging.

The gesture detection is achieved by using a Kinect sensor bar, the OpenNI [2] 1.0.0 API and PrimeSense's [3] NITE 1.3.0 Middleware. The API provides some methods to easily detect and track the user's hand. Various gestures can be detected. In this module, we choose to use the following three gestures based on their naturalness and recognition accuracy.

1. Raise-hand gesture: User raises his/her hand.

2. Hold gesture: User holds his/her hand at a certain position for 2 seconds.

3. Push gesture: User pushes his/her hand towards the camera.

Besides the hand tracking and gesture recognition, different colours have been mapped to different cursor states to improve the user's understanding of what is currently happening. Colours make the visual system much friendlier while enhancing the overall comprehension.

The screen interaction is designed as follows:

1. To select an action, a user performs the Raise-hand gesture. When his or her hand is detected and tracked, a blue point shows up on the screen, indicating the user's control pointer. The Interaction Screen implements an offset shifting mechanism to make sure the user can reach the whole screen without too much movement.

2. By default the menu icons are translucent to avoid distracting the user from the video conferencing. When a user moves his or her hand over an icon, the icon lights up to give user the feedback of interaction.

3. If the user wants to select an icon, he/she can perform a Hold gesture by focusing the blue pointer on the icon for 2 seconds. The pointer will turn green, indicating it is now waiting for the confirmation gesture.

4. To confirm the selection, user performs a Push gesture towards the camera. After a successful push, the control pointer changes to red and a message is displayed on the top left corner of the screen to verify which action has been chosen. This signal will be transmitted through the network to the remote location, and trigger the corresponding subsystem via Bluetooth. Alternatively, the user can cancel the choice by moving away from the button area.

5. After the desired icon has been selected, other interactions are possible while the previous selected action happens remotely (e.g. serving food, transporting food, displaying picture on tablecloth) is still continuing. The interactive session ends when the user rests his/her hand on the table, ending hand tracking. Then, the menu automatically disappears, returning the Interaction Screen to the normal video conferencing mode.

Overall, the integrated CoDine system provides a mediated platform to enrich the mealtime interactions for remote families, with the purpose of enhancing the feeling of co-presence while dining in different locations. Through embedding computerized devices into normal dining table, a series of intuitive and interactive activities under dining context are accomplished to support the feeling of social connectedness. Figure 15 is a photo taken during the prototype testing which gives an overview of how the system works. The testing was conducted to verify the functionalities and robustness of the CoDine system.

CONCLUSION AND FUTURE WORK

In this paper, we present the design and implementation of the CoDine table system as an exploration of using interactive media in dining space to reconnect people. Inspired by our desire to facilitate co-dining, the system augments and transports the experience of communal family dining. Through shared dining activities, including serving dishes remotely, transmitting animated textile display and physical edible message, CoDine aims to provide a new solution to connecting the dining experience between people in remote locations, creating a sense of co-existence among family members who may be physically apart.

While we have conducted prototype tests during the implementation to verify the CoDine modules function, our next step is a user study to assess whether CoDine enhances engagement between fellow co-diners. This will also help us to better define and improve the user experience and user interface. Certain combinations of modules might lead to more successful feelings of connectedness between co-diners. Feedback from users will help us better understand the novel interactions that push the experience of using CoDine beyond that of video conferencing.

Our research explores how interaction with familiar but intelligent everyday environment and artefacts can be used to enhance meaningful interactions in dining situation, going beyond ambient sensing and computing, to the level of subconscious connection between human beings. As we move towards the era of intelligent environment everywhere, it is important that researchers adequately understand the power interactive media and ubiquitous computing have to increase the richness of human experience. We hope the CoDine system will provide insights on designing context-aware interfaces that emphasize experience over efficiency and shared interaction over information.

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