ABSTRACT
Social isolation among the elderly who live alone is an emerging social concern. A society in which elderly people have fewer offspring or have children who live far away increases the number of people living alone. Inevitably, these isolated adults gradually lose their connection with society and their social skills worsen. FridgeNet is proposed to promote social activities for these people. By automating and encouraging the sharing of their diet information, mutual support in the virtual community is established. Continual communication and discussion further promote physical social activities such as groceries shopping with their peers. Based on the empirical results, this study concludes that FridgeNet is capable of increasing their social activities. 9 of 15 participants reported that they increased their interactions and received more attention from their families during the 3-month pilot study.

Author Keywords
Human Factors; Design; elderly people; FridgeNet; health and nutrition.

ACM Classification Keywords
H.5.m. Information Interfaces and Presentation (e.g. HCI): Miscellaneous

INTRODUCTION
Research in many cultural settings has indicated that elderly people who choose to remain in their original homes and communities, despite their children living far away, often end up living alone [3]. Based on the U.S. Census in 2011, 29% of senior adults in the U.S. (8.1 million women and 3.2 million men) live alone [4]. A portion of this population gradually loses their connection with their families and friends because of isolated living situations and deteriorating social skills. A survey conducted by the Joseph Rowntree Foundation revealed that 19% of seniors in the U.K. who live alone communicate with their families on a face-to-face basis less than once a month [5]. In addition, 17% of them are in contact with their families, friends, and neighbors less than once a week; instead, television becomes their main form of company [7]. Gradually, these people lose their ability and willingness to communicate with others and often feel estranged and lonely for the remainder of their lives.

The fast pace of modern life further enlarges the gap between elderly people and the rest of society. They no longer remain informed about the world and express diminished enthusiasm for many former interests. Furthermore, the fast-paced lifestyles of younger generations results in having less time and patience for their parents and grandparents. BBC News [2] reported that more than three million people feel disconnected from the modern life and isolated from society. The lack of connection to the rest of the world affects people’s health and can lead to severe mental illness, such as depression [1]. Based on these facts, a social technology is introduced to assists elderly people in re-establishing communication with their families, old acquaintances, and making new friends.

Some researchers believe that a convenient interactive platform can help people to overcome their isolated living situations. They are encouraged to use the social technology to participate discussions of their living concerns with their peers and families [14, 16]. Common topics of interest among elderly population are chronic diseases, personal life histories, and diet suggestions. Internet and wireless health technologies can provide health-related information, record and update personal and medical information, and offer remote health services to the community. Their daily activities and personal health conditions can be monitored, recorded, and summarized using cloud health care services; thus providing valuable health care information for personalized diagnosis. Their families can better understand the health and social conditions of their parents and obtain basic knowledge to help their parents. Nevertheless, medical information is so personal and private that most people do not like to share it openly. To address this privacy concern, Waycott et al. [17] indicated that by sharing some daily photos and associated stories instead, elderly people can express themselves creatively and have regular communication with their friends as well. Nevertheless, it has been reported that some efforts to engage participants in the interests of their peers have been unsuccessful because of different life experiences.

Healthy diets and lifestyles can be another topic to be addressed [10]. Because body composition and the health conditions of elderly people changes with age [9], they require nutrition information updates. Nevertheless, the process of searching nutrition information is time-consuming and often unstructured. In addition, requiring people to remember the food they consume daily and compare with their recommended intake is impractical because they are likely to forget and confuse about what they have eaten. As a result, a system that enables people to log their dietary intake and look up nutrition information is necessary. The logged and cached nutrition information can be shared with other peers who have
similar nutrition related concerns and with their families who are looking for help in caring for their parents.

SOCIAL ACTIVITY PROMOTION FOR ELDERLY PEOPLE

Social activity has been a popular area of research since the introduction of social network media. A growing interest exists concerning the design and implementation of suitable social networks for aging populations as a means of reducing their experienced social isolation [11, 13]. Some researchers have suggested that elderly people should participate in social networks to virtually connect with their families and friends, particularly if they live in isolated environments. For example, Burmeister et al. demonstrated that online communities can provide a space for elderly adults to share their life experiences and to create mutually supportive virtual communities. As elderly participants increase their online activities, they begin to value their participation in and contributions to a virtual community [8].

FRIDGENET: SOCIAL ACTIVITY VIA DIET SHARING

FridgeNet (Figure 1) is designed for recording personal food intake information and promoting communication and social activity among senior citizens. The system employs sensor-equipped processing units (tablets mounted on standard refrigerators) and a cloud service to store and propagate food information. The system automatically stores users’ dietary histories and downloads the corresponding nutrition information identified in the users’ personal dietary histories. Similarly to existing social networking websites, the system enables users to post comments, pictures, and leave voice messages. The tablet-system also serves to propagate aggregated diet information among peers. Users can evaluate their nutrition intake by comparing their dietary history with other FridgeNet users. People can engage in FridgeNet social activities by regularly posting personal stories and subscribing to food-consumption information within their online community. Furthermore, shared diet information can immediately assist those newcomers undergoing body condition changes during aging to adjust their diet styles.

Sensor-driven Interaction

Common inertial sensors are used on the tablet for automating the data recording process. When a user opens the fridge, the corresponding fluctuation is detected by the built-in accelerometer of the tablet. A prompt message is then triggered that instructs the user to scan a grocery receipt or select the food item name and take a picture to the food item taken out of the fridge. Both scanned receipt images and food snapshots are uploaded to the web service after recording. The item names on the receipt are recognized by an optical character recognition library [12] installed on the server-end. Information is processed by the FridgeNet software on the tablets and stored in the local database for periodic updating from the cloud server. An averaging peer diet intake information of every FridgeNet entity are accumulated in the cloud-end, so that each elderly participant can track their own diet habits and compare with this averaging truth from an elderly group daily. Therefore, a WiFi connection is required for each FridgeNet-enabled tablet. WiFi connectivity also provides FridgeNet-location information. This information is used in the Buy2+gether service when a user enables the service and accepts invitations from peers.

Diet Tracking and Nutrition Analysis

Each food item on the receipt is tracked by FridgeNet. Users can browse the nutrition information of the tracked food through simple clicks on the tracked food list. If a food image is available, clicking on the image displays its nutrition information. Personal dietary history can be tracked and aggregated based on the history of receipt scanning. Consumed food is marked by users and recorded in the users’ stored dietary history. Daily and weekly personal nutrition intake are calculated by accumulating the intake nutrition of all consumed food items. FridgeNet then periodically synchronizes individual dietary history, together with the cached nutrition information of newly added food, to the cloud server. The cloud end aggregates and calculates the average daily and weekly nutrition intake of the users. This summarized information is retrieved by FridgeNet when the next periodic update is issued by the cloud server.
Figure 2. Client-Server Fridge Network.

Cloud Updates Visualization

Figure 3. A sample nutritional comparison with peers.

Figure 3 shows a donut chart that compares the differences in diets between the users and the peers. The chart is split into four sections representing four nutrition requirements for elderly people: iron, calcium, vitamin C, and vitamin D. When a user selects one of the four sections, the comparative results between the user and the peers are shown in the center and a pop-up notification appears to indicate the amount the user requires. Each section of the donut chart is color coded based on the level of nutrition that the user requires, where green represents “sufficient”, yellow represents “might be insufficient”, and red represents “insufficient”, and a user can quickly identify the nutrition component he or she lacks. This information is recalculated when an update from the server is retrieved by the FridgeNet tablet. On the right side of the donut chart, recommended foods for the user are displayed. The types of food recommendations are based on the pre-loaded and peer-recommended food types. The order of recommended food is sorted based on the amount of nutrition each item contains and the requirements for the user. For example, Figure 3 shows a hypothetical user who requires 200 mg or more of calcium in his or her daily diet. Thus, the most calcium-rich foods are listed and a recommended intake amount is provided below the food image. Users may click the button next to the image for more recommendations if the current suggestions are not preferred.

Food Recommendations and Response

Whenever a food item is removed from the refrigerator, a user is expected to mark the item name as consumed from the scanned receipt list and take a picture of that item. This action marks the food item as eaten and its nutrition information is recorded in the user’s daily log. If the food item is not fully consumed, the user should take another picture of the food item or simply input how much of the food remains. The current prototype assumes that all food contents inside the refrigerator were consumed by the elderly who lived alone and they are suggested to leave some messages if they share food with some visitors.

Users can selectively choose to provide comments on the food items they like. FridgeNet encourages and facilitates recommendations to peers. When users want to recommend a food item to peers, they can first press and hold the onscreen name or image of the item they want to recommend. A pop-up menu is displayed that confirms the recommendation. Users can optionally add text or voice messages to more adequately describe his or her recommendation. By contrast, if users discover that some recommended food is healthy, they can “like” the item (by pressing an indicator on the screen) or provide comments, and then place the food item in their virtual shopping cart. Figure 4 shows an example of a user who removed an apple from her refrigerator. Few minutes later, she leaves a comment saying she believes the apple is more delicious than the recommended food, cherries, even though cherries contain more vitamin C, as shown in the nutrient database.

Buy2gether
FridgeNet is not only designed to promote virtual social interaction among elderly people, but also to encourage elderly people to meet face to face. The Buy2gether service (Figure 5) is an application that enables senior citizens to send shopping invitations to their neighbors to meet and purchase food together. Users can send shopping invitations based on the following criteria: 1) nutritional requirements, 2) the nearest three neighbors, or 3) an acquaintance (email address required), such as friends or family members. The person who initiates the shopping invitation can specify what he or she wants to buy, when to buy, and the deadline to accept the invitation. If invitations are accepted by the peers within the specified time frame, the participants can form a group and share contact information. FridgeNet helps to determine the most convenient location for the group to meet based on WiFi-positioning information, if requested. Figure 5 shows a FridgeNet suggestion for the most convenient grocery store for the group of participants.

FIELD STUDY

Participants
FridgeNet was evaluated with a group of 15 elderly people (10 women and 5 men) who lived alone and were between 55 and 76 years of age (AVG = 66.27, SD = 6.13). Some participants already knew other participants, but they did not regularly interact before the trial. Among the 15 participants, only five possessed experiences of using tablets for daily entertainment and none of them regularly used social networking media such as Facebook or Twitter. The families of the elderly participants also participated in the trial, although they were mainly observers and participated in a limited way during the study. They were allowed to access a FridgeNet website to see the general nutrition information and the aggregated diet information produced by participants. They were requested to observe rather than to join, except in the following two situations: 1) When a senior family member had technical difficulty in using the FridgeNet system, and 2) When a senior family member sent Buy2gether invitations to them.

Procedure
The whole study lasted 3 months. At the beginning of the experiment, every senior participant was taught how to use FridgeNet by the authors. To ensure safety, participants were recommended to consult with their personal doctors before changing their diet. Health effects associated with iron, calcium, vitamin C, and vitamin D deficiencies, as tracked by the FridgeNet prototype, were fully explained. They were then trained to scan their grocery receipts, photograph the food, read food nutrition information, respond with a "like" and provide comments and recommendations, and send invitations to specific groups of people. At least one family member of each elderly participant joined the training session. To encourage senior participants to use the Buy2gether service, the authors suggested that families of the participants join in shopping events during the first month to help the senior participants to build confidence in meeting their peers. Participants were asked use the FridgeNet system to search for foods containing high percentages of calcium. Additional information about food nutrition was not provided in this study because it was expected that all participants would enjoy the process of determining nutrition requirements and locating that information in FridgeNet more than they would a lecture about nutrition.

Data Collection
Two types of data were collected during the experiment: FridgeNet data and questionnaire feedback. The following sections describe each type of data.

FridgeNet Data
Data from each FridgeNet entity were aggregated to the server (Figure 6). Each data stream included a unique ID. Researchers produced mapping tables to match unique IDs to the senior participants’ personal information. This information was not accessible by participants nor family members. At the end of study, all tablets were collected to examine if any data was not correctly uploaded to the cloud servers and removed any of the participants’ personal information on the tablets. FridgeNet collected food nutrition information and tablet usage log information such as the number of "likes" associated with a food item, comments, and Buy2gether invitation messages.

The primary statistical items used in the study were:
- Insufficient In-take Nutrition Statistics
- Click Rate of the Recommended Food

Figure 6. The information collected on cloud database for analysis.
• Number of Comments and Feedback

• Number of Buy2+gether Invitation Replied

Data and an in-depth analysis are provided in the Results section.

**Questionnaire**

The elderly participants and their family members were asked to complete a questionnaire to provide feedback about their experiences. The participants rated their experiences based on a 9-point Likert scale, where 1 = strongly disagree, 3 = disagree, 5 = neither agree nor disagree, 7 = agree, and 9 = strongly agree. In addition, they were asked to answer a few open questions to suggest improvements to FridgeNet functionality. The questionnaire included the following items:

For Elderly Adults
(Q1) I feel I eat healthily.
(Q2) The system is easy to use.
(Q3) Reminding me what food is in the fridge is useful.
(Q4) I worry about privacy leaks concerning my eating habits.
(Q5) I am more willing to go outside.
(Q6) My children and I communicate more often.
(Q7) Open Question: It would be great if the system had this feature:

For Family Members
(Q1) I am learning about my parent’s eating habits.
(Q2) My parent is in a good mood more often.
(Q3) I feel less anxious that they live alone.
(Q4) I will also use this system if you can provide a version for young adults.
(Q5) The message notification is disturbing.
(Q6) Open Question: It would be great if the system had this feature:

**RESULTS**

This study attempts to answer three questions regarding the functionality of FridgeNet: 1) Does FridgeNet assist elderly people to choose healthy foods? 2) Does FridgeNet promote online social activities for participants? 3) Do the participants engage in more physical social activities after using FridgeNet than before using the system?

To answer the first question, statistics reveal the number of participants who had insufficient nutrition intake during the study period. To answer the second question, two categories of statistics are considered: a) the number of passive online activities the participant engages in, such as viewing food items or messages from peers, and the number of active online social activities the participant engages in, such as responding to peers recommendations with "likes" and personal comments. The last question is answered by determining the way in which Buy2+gether was used during the 12-week study. Each statistics analysis is discussed in the subsections below.

**Insufficient Nutrition Intake Statistics**

Analyzing nutrition intake trends is a method to determine whether FridgeNet improves elderly participant’s food selection. Figure 7 presents the number of participants exhibiting insufficient nutrition intake in 12 weeks. Four major nutrition components for elderly people were tracked: iron (blue), calcium (green), vitamin C (yellow), and vitamin D (red). The figure shows that some of the participants exhibited lower levels of nutrition-intake sufficiency in the first week than did their peers on average. Eighteen insufficient-intake events were marked over 60 samples (15 participants x 4 tracked nutrition components). However, only 14 insufficient-intake events were marked at the end of the study (51.7% improvement compared with the number in week 1). This phenomenon indicated that the diet of the senior participants improved during the study period. One participant, a vegetarian, expressed that she never considered that she possesses insufficient levels of nutrition intake. She eats ample vegetable and fruits every day. However, by using this system, she realized that iron intake is commonly ignored by vegetarians. She quickly discovered that spinach, recommended by another vegetarian peer, could be appropriate for her. Furthermore, some of the participants said that they worried about insufficient nutrition and, therefore, required a system such as FridgeNet to determine their nutrition needs. Based on their feedback and nutrition-intake trends, this study determined that FridgeNet caused changes in the dietary behavior of those participants that possessed low levels of nutrition and was a catalyst for them to consider superior food choices.
the recommended foods were selected more than once in the 12-week period. Popular foods such as apples were selected by all participants. In total, 1273 clicks occurred for all recommended foods in the course of the 12 weeks. On average, 7.07 clicks were produced per week by each person. Figure 8 presents the weekly average click counts of all 15 participants. Although some individuals produced more clicks than others, the click distribution shows that every participant used FridgeNet often to view peer recommendations. The analysis results revealed that the information obtained through FridgeNet was valuable to the senior community.

**Number of Likes and Comments**

In addition to determining whether FridgeNet provides valuable information to elderly people, this study investigated whether FridgeNet promotes online social activities for elderly people. Specifically, this study attempted to determine whether FridgeNet encouraged them to acknowledge and comment during their online interactions with peers. First, the numbers of and trends associated with likes and comments were analyzed. The study was able to establish the frequency with which senior participants participated in food-related discussions. Figure 9 revealed that the participants required approximately 2 weeks to familiarize themselves with the FridgeNet system. Only a few likes and comments were posted in the first week. The bulk of the comments and feedback started to appear during Week 3. In Week 3, 30 “likes” and 15 comments were posted. By Week 12, the number of likes tripled and comments doubled. This trend revealed that an increasing number of people were engaged in actively providing feedback. Even if they did not comment about a certain food type, they still participated by adding a like. Regarding the contents of comments, this study observed that certain food nutrition information was controversial. For example, although spinach is said to contain abundant amounts of iron, many participants deemed it a potential cause of gall stones. Numerous discussions occurred about this concern and one participant stated that he read some articles online to help them become familiar with their peers.

**Number of Replies to Buy2+gether Invitations**

FridgeNet helped in building a virtual community focused on the topic of a healthy diet. It was also expected to promote physical social activities for elderly people by introducing the service, Buy2+gether. Unfortunately, only 11 shopping invitations were sent and only six were accepted during the 12-week study, indicating that this service was not used very often. Only seven events were recorded and the same group of four people were involved in these seven events. Figure 10 presented the people who participated in Buy2+gether service by Week 10. The shopping group originated with two senior adults, grew to three people by Week 7, and to five people by Week 10. The two group leaders were interviewed after Week 12 and stated that they preferred buying food with someone with whom they felt comfortable and that they selected friends based on replies to their recommendations rather than based on those who possessed similar food requirements. In fact, these two leaders knew each other because of the frequency with which they participated in online discussions about food. This demonstrates that online discussion about food nutrition can enhance understanding and familiarity among senior adults. These findings provide valuable information on the effect of the FridgeNet and Buy2+gether systems. Elderly people can more adequately use this system if frequent online interactions or regular social events occur that help them become familiar with their peers.

**Questionnaire Statistics**

Questionnaires were administered to both elderly people and their relatives. Their feedback enabled the evaluation of users subjective experiences related to multiple aspects of the system design and the study's effectiveness in promoting it. The analysis provided an enhanced understanding of user experience of the FridgeNet system.

Figure 11 shows the average response from elderly participants. This study uses the t test for a population mean. This study's null hypothesis is \( \mu = 5 \), which means that, based on the study's participant feedback, the system is unlikely to produce a noticeably positive effect on users. This study's alter-
null hypothesis and validates FridgeNet as effective in promoting outdoor activities.
Q6 (AVG = 7.53, STDEV = 1.77, p = 3.668e-5) rejects the null hypothesis and validates FridgeNet as effective in promoting family communication.

Figure 12 reveals the average response from relatives who receive daily nutrition summaries about their elderly relatives. This study uses the t test for a population mean. The null hypothesis, alternative hypothesis and significance level are the same as those for the elderly participant questionnaire, whereas Q5 and Q6 possess an alternative hypothesis $\mu < 5$.
Q1 (AVG = 7.27, STDEV = 1.67, p = 5.983e-5) indicates that FridgeNet successfully delivers required nutrition information to relatives of participants.
Q4 (AVG = 4.2, STDEV = 1.26, p = 1.378e-2) reflects that young people do not require a refrigerator to promote their social activities. This study's design focuses on the promotion of activity among elderly people who use the FridgeNet system.
Q5 (AVG = 3.93, STDEV = 1.83, p = 1.997e-2) indicates the daily summaries provided to relatives are helpful to understanding their parents' nutrition information.

**DISCUSSION: NUTRITION RECOMMENDATION**

Nutrition recommendations and discussions can be promoted either online or through physical activities. By sharing dietary habits and other comments and recommendations, elderly people in the study group learned to create and maintain a healthy lifestyle. FridgeNet provided a convenient framework, a popular topic for discussion, and a valuable healthy-diet database. Nevertheless, some limitations were revealed in the prototype. For example, although debatable nutrition information can be a topic for general discussion, a doctor’s input is expected. One participant remarked, “I like discussion, but I love conclusion.” The current FridgeNet community did not include medical or healthcare-related professionals. Therefore, if certain discussions contained errors or confusion regarding nutrition information, these may not have
been corrected. A solution is to recruit certified medical professionals to monitor and participate in FridgeNet online discussions. Another approach is to encourage family members of participants to join discussions and provide professional references and articles about the discussed topics. For example, family members can send their elderly relatives monthly or quarterly reports to the medical professionals.

In addition, the system considers neither the different body types nor pre-existing conditions of participants, and it does not completely track the nutrition components of food. Users suggested that FridgeNet could include more intelligent grouping methods for recommending food based on different types of common illnesses and pre-existing conditions. In other words, FridgeNet may be able to provide a more reliable service by categorizing users into pre-defined groups. However, this strategy requires access to personal and medical information. Thus, a tradeoff is necessary in creating a system that offers comprehensive service and ensures privacy.

DISCUSSION: SOCIAL ACTIVITY PROMOTION
FridgeNet not only promotes social activity among senior peers, it also reduces the distance between the elderly participants who live alone and their families. Both elderly participants and their families reported that voice messages were easy to produce through the FridgeNet system but more difficult to respond to regularly. Future research on how to convert voice messages to plain text may resolve this problem. Participants suggested that enabling FridgeNet to automatically schedule general activities could be an effective way to promote both virtual and physical activities among senior participants. Although this suggestion is considered, it should be noted that such a feature may reduce FridgeNet to a general social medium and cause it to lose its purpose as a health-specific tool for elderly people.

REFERENCES