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# iCare Home Portal: An Extended Model of Quality Aging E-Services

THE QUALITY OF LIFE OF SENIOR CITIZENS is a critical issue around the world today. According to the World Health Organization (<http://www.who.int/>), there were 600 million people aged 60 or above in 2000; there will be 1.2 billion by 2025 and 2 billion by 2050. In addition to the thousands of unnecessary deaths that occur every year, missed health care opportunities cost U.S. businesses more than US\$1 billion in avoidable hospital bills and nearly 41 million work days, resulting in the loss of US\$11.5 billion per year, according to statistics from the U.S. Department of Health and Human Services (<http://www.aoa.gov/>). These figures mean that assisted living and home care has become a fast growing health care sector.

Scrutiny of the extant technologies for aging services (see Sidebar 1) reveals that they are invariably aimed at or electronic care (eCare), but overlook social and

behavioral aspects. eCare is an emerging health care field that utilizes Web technologies. Angood<sup>2</sup> identified three eCare trends that utilize the Internet: medical informatics (focused on information), telemedicine (focused on communication), and cybermedicine (focused on global networking technologies). These eCare trends share the belief that maintaining an independent lifestyle is socially important to the quality of life of seniors and caregivers and that it helps to reduce the potential health care costs that are associated with hospitalization or placement in a full-time care facility. Unfortunately, the existing health care or eCare services for seniors are mostly oriented toward clinical gerontology or neuropsychology. They overlook certain dimensions of quality, such as community involvement, consumer participation, and continuous quality improvement.

In this article, we describe an intelligent care (iCare) system that results in an eCare system that is ambient enough to address the social and behavioral aspects of aging services. This iCare system is characterized by iCare ontology that features ambient service accessibility, unbound information reachability, attentive personalized service provision, innovative lifestyle creation, precious digital memory, and seamless social connection. The objective of the system is to provide quality e-Services to the elderly anywhere and at any time via an iCare home portal.

## The iCare Home Portal Framework

The issues associated with existing eCare technologies can be organized into three dimensions: *environmental*, physical, and relationship. The environmental dimension refers to the software and hardware (wired and wireless) required to deploy the iCare infrastructure. The *physical* dimension concerns the issues of independence, safety, and the quality of life of the aging. The *relationship* dimension focuses on social networks that feature meaningful human interactions. The iCare home portal framework expands

these dimensions by adding *decision* as the fourth dimension (See Figure 1(a)). The *decision* dimension represents the collective decisions that are automated to determine the appropriate personalized e-Services, thus enabling the effective delivery of quality e-Services to the elderly. These decisions can be automatically and intelligently rendered using a set of delegated agents that represents the myriad participants who are involved in caring for the elderly.

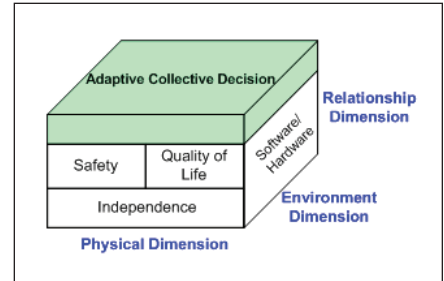
Both the physical and relationship dimensions are fundamental to iCare, as they provide the contextual data required for reasoning during the collective decisions in the decision dimension. The physical dimension is concerned with formal caregiving in which professional caregivers (such as nurses or doctors) are involved. The aims of this dimension are

to promote healthy behavior for problem prevention, to achieve early disease detection to establish disease signatures before symptoms become apparent, and to improve treatment compliance to help people recover smoothly. The relationship dimension, conversely, is concerned only with informal caregivers, such as friends, neighbors, coworkers, family members, content providers, etc.

### Theory Underlying the iCare Decision Dimension

The novel value of iCare rests in its decision dimension, which represents the virtual collective decisions (involving numerous participants) that determine which e-Services (in terms of the service concepts defined below) are appropriate and can be tailored to the context of the elderly. The underlying

**Figure 1 (a). A Framework of iCare Home Portal**



theory of the iCare decision dimension is the Stacey Model.

The Stacey Model (also called the Certainty-Agreement Model) was proposed by Ralph Stacey in 1996.<sup>11</sup> Its objective is to select appropriate management actions within a complex adaptive system that involves multiple

## Aging Service Technologies

Aging service technologies improve lives and society by caring for aging populations and helping the elderly to become healthy and independent and lead vigorous lives. These technologies can be utilized to create caregiver networks that enable people to age in the comfort of their own homes. Examples of aging service technologies include relevant projects that utilize sensors and actuators for correlation with the service aims, such as monitoring occupants, communicating with occupants, and assisting occupants in their daily activities.

There are two principal categories of aging service technologies: care-oriented technologies and environment-oriented technologies. Care-oriented technologies support professional needs and enhance the quality of care and life in terms of the cognitive perspective. For example, mobile technologies are utilized to provide cognitive assistance to Alzheimer's patients. Environment-oriented technologies assist the elderly to live safely and actively.

### Care-Oriented Technology

Autominder is a cognitive orthotic system developed by NASA JSC that helps aging adults adapt to cognitive decline and continue with their routine activities.<sup>8</sup> Autominder provides adaptive/personalized reminders for the activities of daily life and maintains an accurate model of a client's daily plans.

The Assisted Cognition project was developed to enhance the quality of life in patients suffering from Alzheimer's disease and similar cognitive disorders.<sup>5</sup> The systems that were developed can sense an individual's location and environment, learn patterns of daily behavior, and help patients via various interventions.

The Nursebot project was developed at Carnegie Mellon University.<sup>9</sup> The project goal was to develop personal robotic aids with five primary functions: cognitive prosthesis, safeguarding, systematic data collection, remote tele-medicine, and social interaction.

The UbiMon Project investigated health care delivery by combining wearable and implantable sensors (such as a body sensor network system).<sup>7</sup> The project aim was to monitor patients under natural physiological states to detect and prevent transient but possibly life-threatening abnormalities.

The MiCare project is a patient-centric health care environment<sup>12</sup> that focuses on the seamless integration of care services and the context-aware authorization of health care records. The MiCare project combines the care services with multiple roles and manages the authorization of health care records in different contexts.

### Environment-Oriented Technology

The Aware Home is an experimental residence that has two identical and independent living spaces.<sup>6</sup> In this project, occupants were constantly monitored and tracked, and personal information was cautiously collected and stored.

MIT's House\_n is a renowned example of future home architecture.<sup>4</sup> The project constructed prototypes that demonstrated environments that helped people to live longer and more healthily, reduce resource consumption, and integrate learning into their everyday activities in the home.

The Smart House is an alternative smart home environment in which computation is embedded into physical objects.<sup>3</sup> The project attempted to change its environment proactively to provide services that promote an independent lifestyle for the elderly.

The Gloucester Smart House was developed using several integrated and stand-alone smart house systems to assist people with dementia.<sup>1</sup> The systems were built in the home to prevent flooding, to detect when the user got up in the morning, to provide messaging through voice units distributed throughout the house, and to monitor cooking devices and turn them off when smoke or gas was detected.

The uHouse is a comprehensive home health monitoring system developed in South Korea that monitors a patient's biosignals and activities.<sup>10</sup> The objective of the uHouse project was to develop a system that monitors a patient's biosignals continuously without using obtrusive devices.

The literature indicates that the two categories of aging service technologies (such as, care-oriented and environment-oriented) are related to environmental and physical dimensions (environment-oriented technology focuses on environmental assistance and care-oriented technology concentrates on mental assistance). That is, these systems are predominantly oriented toward sensor technology in clinical gerontology or age-related motor/cognitive neuropsychology. Progressing beyond environmental and physical dimensions, iCare suggests a novel, quality e-Service that emphasizes community involvement, consumer participation, and continuous quality improvement via the relationship and decision dimensions. Table A compares the components (hardware-based and hardware plus software-based) of various projects under environment-oriented, care-oriented, and home-plus-care technologies. The three specialized components of iCare are: proactive needs identification (proactiveness), collective decision-making for service recommendations (community involvement/continuous quality improvement), and (3) collaborative service delivery and pricing (consumer participation).

**Table 1. Stacy Model equipped with three different principles employed for iCare virtual collective decision making**

		CERTAINTY ABOUT OUTCOMES		
		High	Medium	Low
AGREEMENT ABOUT OUTCOMES	Low	<b>Garbage-Can Principle</b> (presents a decision mechanism with multiple needs and resource constraints) <i>This model combines the Garbage Can Theory and intelligent agents so as to furnish a decision strategy that decides on an appropriate order of needs satisfaction considering the limited resources among the participants.</i>		
	Principle	<b>Brainstorming Principle</b> (reaches virtual collective decisions in a brainstorming session with the collaboration of a set of learning agents) <i>This model utilizes the Q-Learning method grounded in three capabilities of human associations (e.g., similarity, contiguity, and contrast) and combines brainstorming theory and intelligent agents to attain a collection of automated decision agents.</i>		
	High	<b>Case-Based Reasoning Principle</b> (improves the quality of life for the elderly from the mental perspective) <i>This model presents a Substitution-Based Case Adaptation CBR to analyze the causes of changes in the mood status of the elderly. Furthermore, it infers the reasons for the changed mood in a sensor networking environment and furnishes aid proactively.</i>		

In the iCare environment, a real person with a well-defined role, such as a family member, friend, doctor, or neighbor, is represented by an agent that assists and acts on his or her behalf to perform collective decision-making and somehow has the ability to adapt and learn. This agent is connected to the person in terms of the provision/modification of the knowledge bases it embodies. However, the elderly are also involved in the service provision by accepting or rejecting the e-Services that are collectively recommended.

In iCare, the decision dimension (such as, virtual collective decision-making by consumers) is a significant feature, as it captures collective user participation in the care goal (such as, the appropriate contextual care service) and the subsequent status of goal-fitting (such as, continuous care quality improvement). The Stacey Model is employed in this study as the theoretical foundation to resolve collective decision problems under the dimensions of certainty and agreement.

### iCare e-Services

Based on care-taking and care-giving functions, and assuming that the elderly in question are not seriously ill, iCare e-services can be categorized into taking iCare e-Services and giving iCare e-Services, as follows.

► Giving iCare e-Services: e-Services

participants based on the degrees of certainty and the levels of agreement (Table 1). Many different disciplines in collective decision-making correspond to different zones of decision problems. In accordance with the different degrees of certainty and agreement, the disciplines employed by iCare include garbage-can reasoning, brainstorming, and case-based reasoning.

In the simple zone of collective decision-making, decision problems are straightforward to plan and control (such as, close to certainty and agreement), and the case-based reasoning principle is adopted to resolve them. In

the chaos zone, decision problems are difficult to handle without conformity (such as, far from certainty and agreement). The zone between the simple and chaos zones is called the “zone of complexity,” and it embraces the principles of garbage-can reasoning and brainstorming.

Collective decision-making is automatically triggered by the iCare home portal based on the needs information supplied by the elderly. Each zone of the collective decision is equipped with a self-learning mechanism (as indicated in Table 1) that is capable of continuous improvements in decision-making.

**Table A: Comparisons among Environment-Oriented Technology, Care-Oriented Technology, and iCare Technology**

		Environment-Oriented Technology					Care-Oriented Technology					Home+Care Technology
Component		Aware Home <sup>6</sup>	House_n <sup>4</sup>	Smart House <sup>3</sup>	Gloucester Smart House <sup>1</sup>	uHouse <sup>10</sup>	Autominder <sup>8</sup>	Assisted Cognition <sup>5</sup>	Nursebot <sup>9</sup>	UbiMon <sup>7</sup>	MiCare <sup>12</sup>	iCare
Hardware-Based	Nursing					✓			✓		✓	✓
	Daily Living Assistance	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Sensor Monitoring	✓	✓		✓	✓		✓	✓	✓	✓	✓
Hardware + Software Based	Social Network	✓						✓	✓			✓
	Early Detection of Problems	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Proactive Needs Identification (proactiveness)											✓
	Collective Decisions for Service Recommendation (community involvement/continuous quality improvement)											✓
	Collaborative Service Delivery and Pricing (consumer participation)											✓

that engage the elderly to contribute as individuals or communities, thus unfolding two further sub-categories of e-Services (individual-centric and community-centric).

► Taking iCare e-Services: e-Services that engage the elderly to attain four kinds of resources (physical, mental, combined, or informative), as follows.

- Physical: for example, *telemedicine e-Services* that provide remote medical assistance.
- Mental: for example, *home-movie e-Services* and *connection-oriented e-Services* that aim to aid lonely aging persons based on social connections.
- Combined (mental plus physical): for example, *therapy entertainment* that is presented to elderly persons (individual-centric) or groups (community-centric).
- Informative: for example, the *provision of information* (specialized, generic, or only for personal information management) to the elderly.

### iCare e-Service Ontology

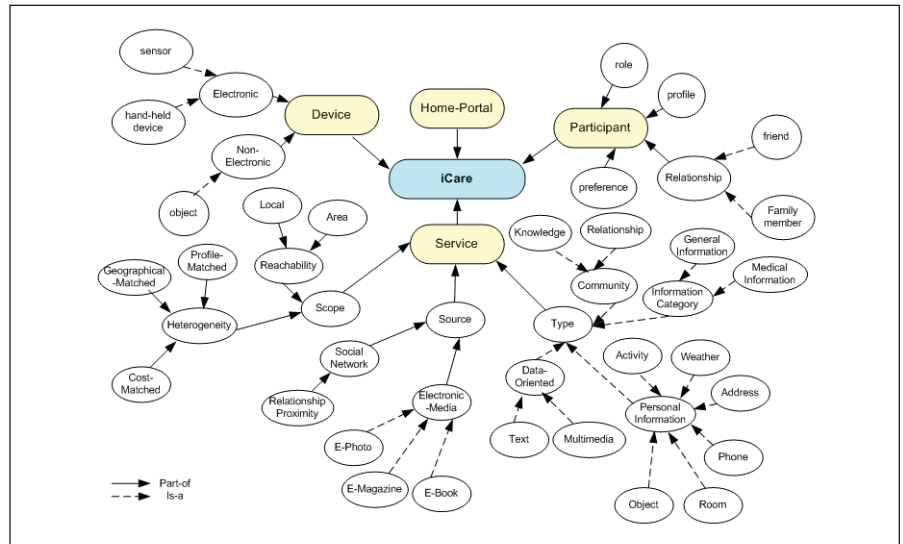
Figure 1(b) displays the ontology of the iCare e-Service, which consists of four primary concepts (home-portal, service, device, and participant). The home-portal is a smart interface that connects the elderly with service providers and other participants. The other three concepts are as follows.

► The service concept is characterized by three high-level attributes (scope, source, and type).

- Scope refers to the degree of heterogeneity and reachability that a service embodies (such as, how specialized and wide-ranging the e-Service is).
- Source indicates the resource origins that the e-Service draws upon (for example, human beings or content providers).
- Type specifies the form in which an e-Service is rendered. The form could be data-oriented (such as, text or multimedia), community-oriented (such as, a community channel for the elderly), personal information-oriented (such as, information management that pertains to the daily life of the aging), or information category-oriented (such as, specialized information such as medical or financial information).

► The device concept refers to a set of devices (involved in the iCare e-Servic-

Figure 1 (b). iCare Ontology



es) that can be divided into two categories (electronic and non-electronic).

- Electronic refers to the electronic hardware involved in the iCare environment (for example, sensors, and handheld devices).
  - Non-electronic indicates the non-electronic equipment in the person's surroundings (such as, myriad objects).
- The participant concept is characterized by four attributes (role, relationship, profile, and preference).
- Role indicates the character played by the participant involved in the iCare environment (such as, the elderly person, the caregiver, the family member, or the remote caregiver).
  - Relationship refers to the relationship between the participant and the elderly person.
  - Profile refers to the demographic profile of the participant.
  - Preference refers to the preferences of the participant (in the example of an elderly person, these include the set of e-Services that he or she consumes in the course of his or her habits and hobbies).

In Figure 1(b), node refers to a concept described above, a dotted arrow line indicates an “is-a” relationship from a subclass concept to a class concept, and a solid arrow line denotes a “part-of” relationship from a partial concept to an integral concept.

A home-movie e-Service example is utilized to explain how an e-Service can be described using the concepts de-

fined in the iCare service ontology. This service provides a customized video that comprises photos, pictures, and videos (most likely provided by remote participants or the media). The objective of this e-Service is to entertain elderly people who are lonely by combining media provided by family members or friends. The characteristics of the home-movie service are as follows.

- **Source:** an appropriate social circle based on the “relationship proximity” (high, medium, and low) of the elderly and their given recognized “mood status” (for example, happy or homesick).
- **Type:** a data-oriented form that uses a multimedia format.
- **Scope:** “profile-matched” heterogeneity and designated areas of reachability with respect to an elderly person's preferences.

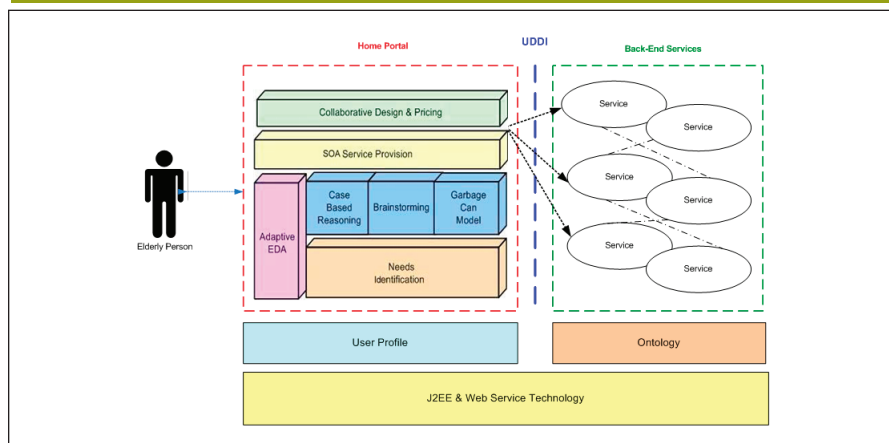
Using the iCare service ontology, care e-Services can be well delimited according to aspects of the expanded eCare model. Furthermore, this study can construct agents (who are committed to this ontology) who engage in virtual collective decision-making using the iCare decision dimension.

### Implementation of the iCare Home Portal

To demonstrate the features of the iCare home portal, we have implemented a prototype with the Service Oriented Architectural (SOA) strategy, as depicted in Figure 2. There are three possible types of collective decision blocks for service recommendation:



**Figure 2.**

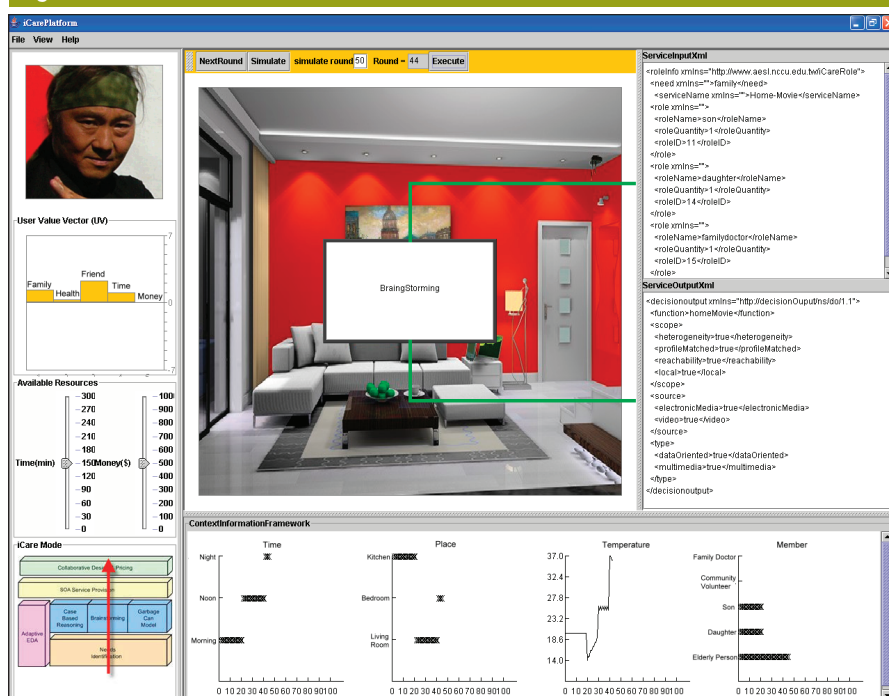


the case-based reasoning model, which provides regular decisions within a single need; the brainstorming model, which offers innovative decisions within a single need; and the garbage-can model, which renders appropriate decisions within multiple needs and resource constraints. Here, we demonstrate the brainstorming model.

Brainstorming is a collective decision-making application that involves numerous participant types (with moderate degrees of certainty and agreement) to determine appropriate e-Services that are tailored to the context of the elderly. This type of collective decision-making is good for elderly people who are extroverted and favor

innovative and interesting lifestyles. For instance, a collective decision could be derived via brainstorming in a situation in which the agents for a son, a daughter, and the family doctor aim to discover collectively an innovative e-Service for a rainy day (e.g., an indoor yoga exercise) that would have the same effect as an outdoor exercise the elderly person needs to perform routinely.

Figure 3 demonstrates a snapshot of the iCare system running under the brainstorming model. The user value vector on the left-hand side represents the elderly person's view of the relative importance of the aspects of family, health, friends, time, and money (from 7 to -7). The available resources (for ex-

**Figure 3.**

ample, time and money) of the elderly and their caregivers are exhibited at the bottom of the left-hand side. The iCare system also shows the current collective decision model (such as e-Brainstorming). The bottom of the right-hand side shows the elderly person's dynamic contextual information (such as, time, place, temperature, and the members of the household). Finally, the detailed XML input/output information of the services in the current decision model is listed on the right-hand side.

In the iCare Home Portal, a specific mechanism – *Semantic Ideation Learning for Agent-Based e-Brainstorming* – has been developed and integrated to represent the participants who engage in an idea generation session for care service recommendations. This mechanism provides an ideation protocol that resolves the problems associated with the three boundaries (understanding, cognitive, and endurance boundaries), and thus idea quantity could be considered to be the dominant measure of e-Brainstorming effectiveness.

Assessing this agent-based e-Brainstorming mechanism within the service scope of iCare involves justifying the improvement in the number of ideas generated (such as group creativity) and the diversity of the ideas created in recommending innovative care services. An idea in the context of iCare represents the recommendation of an e-Service. Accordingly, the set of valued ideas generated is equivalent to the set of recommended e-Services.

Without a loss of generality, an exemplar of the given experiment settings is given as follows: (1) a universe of eight e-Services (such as, possible ideas for services to be delivered) for the mental needs under consideration; (2) up to 10 possible roles (such as, agents representing son, or daughter) involved in e-Brainstorming, each of which embodies its own knowledge of the domain of mental needs (simply represented by the correspondent marks made with respect to the e-Services); (3) a benchmark greedy mechanism that randomly selects an e-Service from the existing knowledge of relevant domains for service recommendations; and (4) two metrics, Average Service Types and Service Diversity Rate (see definition here), which are used to inspect the mechanism's performance. Figure 3 shows

the portal with the e-Brainstorming mechanism, and Table 2 presents the evaluation results.

### Definition of Metrics

$$\text{Average Service Types} = \sum_{i=1}^N t_i / N \text{ and}$$

$$\text{Service Diversity Rate} = (\text{Average Service Types} / T) * 100 \%,$$

where

- $N$  = total number of experiment iterations,
- $t_i$  = number of Service Types generated from the  $i$ th experiment, and
- $T$  = Number of available e-Services.

### Performance Benchmarks

This study benchmarks the greedy model against the e-Brainstorming model by comparing the number of types and the diversity of the generated e-Services with the different numbers of roles (three, five, or seven) that are involved in the decision process to justify the capability of group creativity in e-Brainstorming. It can be seen from Table 2(a) that when the e-Brainstorming mechanism does not account for agent knowledge learning capabilities (for example, agents are without the function to forward valued ideas to the idea knowledge base of every session participant to expand domain knowledge as the ideation rounds go by), a relatively good performance of the e-Brainstorming mechanism is attained (the different numbers of participants involved) in both the Average Service Types (such as,  $3.7 > 2.77$  when roles = 3) and Service Diversity Rate ( $46.25\% > 34.58\%$  when roles = 3) in comparison with the greedy approach. However, the results also reveal that the performance gap becomes small when the number of roles is increased.

When agents have the capability to gain knowledge in e-Brainstorming, the performance improvements increase (such as, Table 2(b) shows the increased improvements of a case with three participants). The number of Average Service Types increases according to the extended VIQ number (from 4.8 to 6.07 when the VIQ is 1 and 3, respectively). A VIQ is a specified number of new idea instances added to the idea knowledge base. The Service Diversity Rate percentage also increases. Finally, in Table 2(c)

**Table 2. Performance of the e-Brainstorming home portal**

(a) e-Brainstorming performance benchmarked against the greedy approach (if the agents are without knowledge learning capabilities through the ideation rounds)

Decision Model		Roles = 3	Roles = 5	Roles = 10
Greedy Model	$\sum_{i=1}^N$	83	118	182
	Average Service Types	2.77	3.93	6.07
	Service Diversity Rate	34.58%	49.17%	75.83%
e-Brainstorming	$\sum_{i=1}^N$	111	148	200
	Average Service Types	3.7	4.93	6.67
	Service Diversity Rate	46.25%	61.67%	83.33%

(b) e-Brainstorming performance with respective VIQ values (if each agent has knowledge learning capabilities through the ideation rounds in the case of 3 roles)

Metrics	without knowledge learning	VIQ = 1	VIQ = 2	VIQ = 3
$\sum_{i=1}^N$	111	144	153	182
Average Service Types	3.7	4.8	5.1	6.07
Service Diversity Rate	46.25 %	60%	63.75%	75.8%

Note: VIQ represents a specified number of new idea instances added into the Idea Knowledge Base

(c) Performance comparison in terms of Service Diversity Rate

Decision Model	Roles = 3	Roles = 5	Roles = 10
Greedy Model	34.58%	49.17%	75.83%
e-Brainstorming – 1 Ideation Round (i.e., not yet brainstorming)	18.33%	36.25%	44.17%
e-Brainstorming – 4 Ideation Rounds	46.25%	70%	83.33%
e-Brainstorming –13 Ideation Rounds	70.83%	96.25%	100%

it can be seen that the mechanism's performance improvement in the Service Diversity Rate is proportional to the number of participants involved (such as roles) and the number of ideation rounds (such as ideation rounds). For example, the Service Diversity Rates are 46.25%, 70%, and 83.33% when the number of roles is three, five, and 10, respectively, for the four ideation rounds in e-Brainstorming.

In short, this application demonstrates how the iCare model (augmented with the decision dimension) engenders consumer participation (in the form of virtual collective decision-making by agents working on behalf of the son, daughter, or family doctor of an elderly person, who connects to the agents in terms of their knowledge provision) in the recommendation of appropriate contextual e-Services for the elderly (in the form of the generation of a set of valued ideas, with the recommended e-Service being the most valued idea). Furthermore, a greater number of participants and ideation rounds in the decision process results in a higher


Service Diversity Rate and more Average Service Types; that is, the results demonstrate that the iCare model ensures not only greater consumer participation/community involvement, but also continuous quality improvements in e-Service recommendations.

### Conclusion

As the worldwide elderly population is expanding much faster than that of the younger generation, electronic care for the elderly is increasingly popular. This study proposes an electronic iCare model that utilizes collective decision-making to underscore the desired care quality elements of consumer participation and continuous quality improvement. This model goes beyond environmental, physical, and relationship aspects to envision possible forms of iCare e-Services and the ontology required to empower agents to fulfill the collective decision process.

The impacts of the iCare model are threefold. First, the iCare home portal provides the elderly with multiple types of care, a personalized service, and real-

time monitoring features. Second, the iCare platform can discover and respond to the needs of the elderly by utilizing cultural and technological resources, thereby enriching their lives and earning their trust in the service. This helps to alleviate the burden on their families and society. Third, the iCare platform is capable of combining various application services (such as, portal sites, Web services, and home management) to form an eCare service industry chain that can provide more innovative, multi-oriented, and caring services to the elderly and to society as a whole.

We hereby urge existing service providers to re-package their eCare content or services. We also call for action by governments around the world to improve the efficiency of their eCare infrastructures by developing and deploying the iCare home portal to ensure that society becomes a more welcoming place for the elderly once eCare infrastructures and services are in place. 

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