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Computer-Aided Design
AND APPLICATIONS

Exploring A Designer-oriented Computer Aided Design Interface for Smart Home Device

Shang-Yuan Chen[1], Shu-Fen Chang[2] and Yi-Feng Chang[3]

[1]Feng Chia University, shangyuanc@gmail.com
[2]Ming Chi University of Technology
[3]Feng Chia University

ABSTRACT

In the cloud computing network environment, the main challenge is to manage, link, and coordinate the humans, objects, or human and objects in the smart home industry, so that tasks assigned by the user can be accomplished. To be successful, the smart home industry, designers, and users need to work hand in hand. The "computer aided design interface for smart home device" is a "designer-oriented" interface. It can be defined as a cloud computing-based design tool, based on the theorem of intelligent agents, in assisting home designers to develop smart home device according to user needs, technology and service provided by smart home device companies, and the whole integrated space. The interface is software which helps designers in providing the smart living space professional designs and services. Based on the literature retrospective and case study, the study concludes the developmental dimensions for smart house. The following two are recommended for the knowledge recreation of interface design: 1) the theory of intelligent agents and 2) scenario-oriented design. The "computer-aided design interface for smart home device" allows "designers" to offer "home users" the visual stimulation, adoption of a smart home device system, and budgeting advice.

Keywords: cloud computing, SaaS, intelligent agent, smart living space.
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1 MOTIVATION AND GOALS

The rapid development of ICT industry is a breeding ground for the "smart living space industry" in Taiwan. Therefore, it is important to study the Internet infrastructure, platform and applications in order to promote the contact, communication, and cooperation among users. Based on smart home design, the study suggests a "designer-oriented" "computer-aided design interface for smart home device," which will help intelligent living space participants (the designer, home user, and industry) to communicate, cooperate, and make decisions. The following matters assist a "space designer" to provide professional advice regarding the smart living space: the situational requirements of smart homes' occupants, the coordination of objects in the space, the technology of home device company, visual stimulation of space settings, and budgeting conditions.

2 LITERATURE RETROSPECTIVE

The development of modern smart living space is closely related to emerging technology and applications. In the following, we briefly explore the "Evolution and trend of smart houses" and the modern "cloud-computing network environment."

2.1 Evolution and Trend of Smart Houses

"A smart house is defined as a building equipped with computing and information technology which can expect and respond to user's needs; the technology management is introduced to a household which links the latter to the world, in order to provide comfort, security, and entertainment". [1]

In the early twentieth century, "electricity" is introduced to households. The clean and convenient energy, "home appliance," and relevant applications dramatically changed the home technology. In the late twentieth century, the "information" and communication technology are introduced to the households, and the "internet" becomes more and more influential. From the macro-perspective, the information revolution changes the home technology in the following dimensions: (1) control technology and interface design, (2) context-awareness, (3) personal system, (4) information and communication technology, and (5) intelligent systems. [6]

From the academic point of view, DARD (1996) [8] concerns the home activities and information flow (human flow; energy flow and information flow). BARLOW (1998) [4] focuses on the three types of technology: (1) universal technology which provides more precise systems; (2) context-specific system which is more practical, and (3) individual system targeting housewives. GANN et al. (1999) [9] emphasizes the usefulness, and the two types of smart houses are distinguished. The first is the traditional definition for home automation, which emphasizes smart home applications. The second involves the information interaction and communication computing, which exceed the functions of a tradition home. JEDAMZIK (2001) [12] points out the four elements of a smart home: (1) user interface, (2) technology, (3) information, and (4) service. In practice, homes with "wired-control" were initiated in the 1960s. Business applications of home application started in the 1980s. The development of electrical equipment includes home digital system, units and other new device. Smart home items also include construction, electricity, architecture, energy saving, and telecommunication. From 1980 to 1990, the following four automation index are developed for smart buildings: (1) building automation (BA), (2) office automation (OA), (3) communication automation (CA), and (4) architecture and environment integration (AE) [2]. The emergence of "office in the pocket" also indirectly promotes intelligent buildings. In the 1990s, smart houses appear in the mass culture and fashion media along with the concept of "ubiquitous computing;" intelligent technology becomes part of home living. Under the globalization, in the 2005 Conference on Industrial Technology Strategy held by the Executive Yuan of Taiwan, the "strategy for smart living space" was proposed, in order to integrate the high tech industries (ICT industries such as the electronics, electrical engineering, materials, information and communications) and traditional construction industry [19]. In 2009, the Architecture and Building Research Institute of Ministry of the Interior created the "Exhibition Center for Smart Living Space." Home living after the information revolution is now called "Living 3.0," and a smart living includes: (1) the infrastructure, (2) safety monitoring, (3) energy-saving and sustainability, (4) health care, and (5) comfort and convenience. Smart living is promoted to the public livelihood [3].

2.2 The development of Cloud-computing Network Environment

"Cloud Computing: Web-Based Applications That Change the Way You Work and Collaborate Online" [13]

From top down, the network-based smart living environment involve three levels of techniques: (A) infrastructure; (B) platform, and (C) applications. Since 2002, the Executive Yuan promoted the E-Taiwan, M-Taiwan, and U-Taiwan projects [7] (see Table 1). The infrastructure includes innovations in wireless communication technology, municipal-level integrated wiring system, and IPv6 protocol. The platforms change from the "distributed intelligent environment" to the "era in which information is away from the personal computer." As a result, smart home device can be readily controlled by a micro-computing device (such as mobile phones, PDA, GPS, notebook, media center and music players) without a central control room. The device is connected to the internet and has ubiquitous service based on user conditions. Since 2008, IBM and Google promote the "cloud-computing." It is expected to change software sales and distribution, which used to be on a single host, to mass parallel cloud-computing. On the other hand, Microsoft actively expanded the modified "cloud-client computing". [15]

	E-Taiwan	M-Taiwan	U-Taiwan
Duration	2002-2005	2005~2006	2007~2011
Infrastructure	Building broadband cables and fiber to the home (FTTH), Information communication theology (ICT) for IPv6	Mobile communication WLAN, The dual-network integration , The development of multi-mobile applications	Construction of sensor network, Network convergence , Ubiquitous network
Platform	Desktops, Microsoft operating system	Laptops, cell phone, PDA, Microsoft operating system, Google platform	Eee PC, Cell phone, PDA, smart home device, operating system based on cloud-computing
Application	Five major frameworks: home broadband, e-living, e-commerce, e-government, and bridging the digital divide	Accelerating the fix-network operators on FTTH, integrating mobile and wireless internet, constructing the national duo-network environment, promoting m-living, m-learning, m-village, and other wireless applications	Smart sensor-based environment, simple and convenient interface, innovative service targeting public needs, safe and reliable social environment, and safe and thoughtful service
Goal	The mission of e-Taiwan is to make Taiwan the leading e-country in Asia and a high tech service island by information and communication technology.	e-learning + application (mobile living, mobile learning, mobile service)	The "e-service and ubiquitous network" will make Taiwan a safe and convenient society

Tab. 1: From E Taiwan, M Taiwan to U-Taiwan.

The internet connects the wireless local area network (WLAN), server, work station, personal computer, and facilities. As a result, cloud-computing is very powerful. With the cloud-computing technology, it is important to develop cloud-computing services. To meet users' expectation, the biggest challenge for cloud-computing service is the safety of data storage, faster connection and operation, and standardization. The cloud-computing service needs to be more efficient in communication and cooperation. Since the development of internet in the 1960s, the following measures have been taken: creating a standardized protocol, the evolution from Ipv4 to Ipv6 address, searching means of communication by TCP/IP, and creating a common internet interface [17]. Table 2 represents the developments of computing technology, know-how, and comparison on client-server computing, peer-to-peer computing, grid computing, ubiquitous computing and cloud-computing. Taiwan gradually emerges from E-Taiwan, M-Taiwan, to the ideal of U-Taiwan.

Cloud services include: communication as a service (CaaS), infrastructure as a service (IaaS), software as a service (SaaS), and platform as a service (PaaS) [17]. SaaS gradually becomes a common distribution mode for service-oriented internet technology. Under the traditional software distribution, consumers purchase the software and install it on personal computers; as a result, software is viewed as a product. SaaS is another software distribution model. Applications are hosted by product companies or service provides, and users pay or have free access to the applications on-line. The costs are reduced because users no longer own the software. On the other hand, users can also jointly accomplish a mission through on-line software.

Type	Client-Server Computing	Peer-to-peer distributed computing	Grid computing	Pervasive Computing/ Ubiquitous Computing	Cloud computing
Since	1975	1980	1990	1991	2008
Brief	Only servers have computing capability, and terminals are for the input and output of commands	Dividing tasks requiring mass computing into many smaller tasks; computing is done on many computers; the computing results are finally sent back	The computing capacity and information service are shared by the internet. The development of grid integrates globally-distributed resources a vast computing resource through Internet so that everyone can share computing resources.	The goal of ubiquitous computing is to create a pervasive network to make information ubiquitous (Marker Weiser)	With the high speed internet, cloud-computing is a combination of client-server computing, distributed computing, and grid computing. It fulfills the ideal of ubiquitous computing. The idea is to share the software or resource on a remote server managed by expert; the users can only access through internet. Software requiring large computing resources is on the server end, only private information is held at the user end. The function of terminal is weakened.
Know-how	Mainframe, server, work station	Personal computer, LAN	Personal computer, internet	Wireless transmission, broadband, IPv6 protocol	Cloud computing service: Amazon, Google App engine, IBM, Salesforce.com
Advantage	Centralized resource management; lower hardware cost; easy to manage	Effectively uses other resources	The coordination of distributed virtual organization and resource-sharing meet the needs of mass computing.	Data is always available; the user can determine the environment based on its background and physical and mental status.	Storage, system administration, data, and applications need not be “owned,” rather, such “services” are available online for free or fees

Constrain	The terminal has no storage; hard to operate	The terminal calculator requires a strong capacity to meet the increasingly complex tasks	Used for large and complex scientific computing or business applications	Required effective integration of sensor, computing, action, and communication techniques	Not accessible without network; the quality depends on the bandwidth and remote resources; security of secret information.
Application	The start of computer applications	The start of digital era	E-Taiwan	M-Taiwan	U-Taiwan

Tab. 2: Computation evolution and comparative analysis.

As a result, the "cloud-computing" network environment and "software service" make "computer-aided design interface for smart home device" a pro-cooperation network platform. With the help of internet, participants contact, communicate, and work together through the text, voice, or video on the internet; thus, participants have better access to decisions. However, the cooperation is not limited to the technology level. Rittinghouse (2010) [17] believes that cooperation is a business platform. Hence, the following three items are especially important: 1). to create a collaborate atmosphere, 2). to modify and adjust the hierarchy in work place and encourage participation in decision making, and 3). to leverage the technology which can breakdown time and special obstacles and change the work type. The Figure 1. shows that under the cloud-computing service, applications (AP) and database (DB) are both in the cloud, and the user uses user interface (UI) to operate software and cooperate via the cloud.

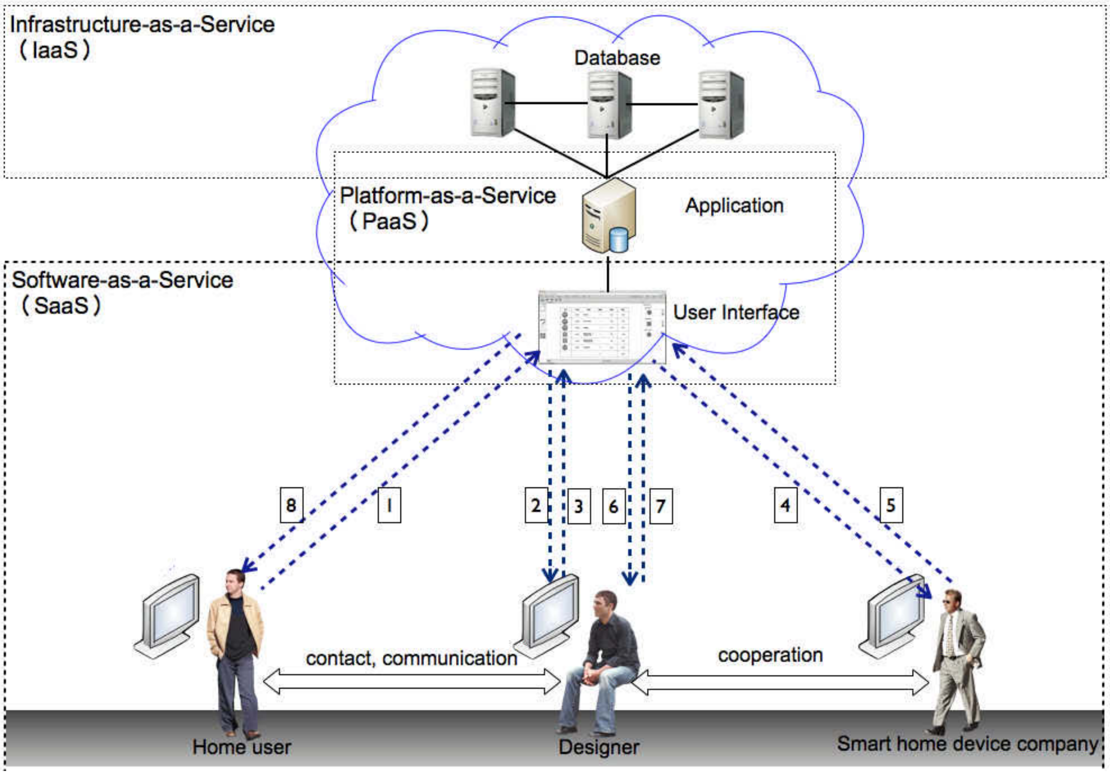


Fig. 1: Users' cooperation via cloud-computing network.

Their relationship is as follows: (1) a home user proposes living demands to the designer on the interface; (2) the designer starts working based on home user's demand; (3) search for suitable smart device on-line; (4) contact smart home device company for relevant product catalog and information, (5, 6) a reference to designers, (7, 8) the designer presents design results to home user on the interface.

3 THEORETICAL FRAMEWORK

Based on cloud computing network environment and software service, the "Computer Aided Design Interface for Smart Home Device" suggested the following two to be the framework for computer-aided software and interface design: 1) the theorem of intelligent agents, and 2) scenario-oriented design.

3.1 The Theory of Intelligent Agents

"The basic module for intelligent agent consists of the sensor, computing mechanism, and actuators. It includes software and hardware that is autonomous and capable of communication, cooperation, and learning." [18]

Intelligent agent is an important research paradigm in modern "artificial intelligence". Under the distributed intelligent environment, it is a tool of knowledge representation for computing and information communication. It is expected to build a collaborative model for the operation and communication between humans, objects, or human and objects in the industry links, based on the intelligent agent theory. From the point of view to build the operating, communication, and collaborative system for objects in the space, the environmental sensor, microprocessor, telecommunication, and network technology create the new intelligent device and lifestyle. From bottom up, under distributed computing, the smart home device include the following elements (A) perception, (B) computing, (C) actuation, and (D) communication, and (E) energy, if viewed as an independent intelligent agent. Take smart skin for example, the project manager examine the theoretic structure of smart house in his thesis, "The study of applying agent-based theory to adaptive architectural environments." The study alleges that the theory of "intelligent agent" is based on Perception - Computing - Actuation (PCA). In other words, for smart buildings that are context-aware, the computing mechanism can perceive and consider multiple percepts, driving architectural element to be adaptive (Figure 2) [5]. However, besides the above advanced "computing technology," recent smart architectural technology also emphasizes the "network," applying it on smaller living spaces. In additional to PCA, the new model requires the ability to "communication;" that is, a smart environment capable of "perception – computing – actuation – communication" (PCAC). The agent group sends messages through common protocol and database. Hence, the coordinating and collaborate "interactions" among agent group are developed (including one versus one, one versus all, or all versus all relationship). The agent group may also communicate with the user through the man-machine interface [21]. The levels of agent and group relationship may change according to the goals and missions [14] (Figure 3). Besides (A) perception, (B) computing, (C) actuation, and (D) communication, the goal of "user-oriented" intelligent living space and "environment-oriented" sustainable energy saving are not always the same. Only recyclable "green energy" can create a safe, secure, health, and caring smart living.

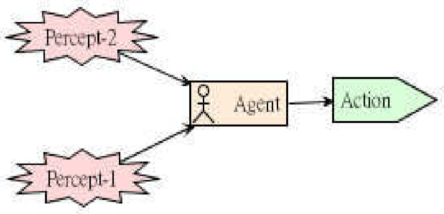


Fig. 2: Module for Intelligent Agent.

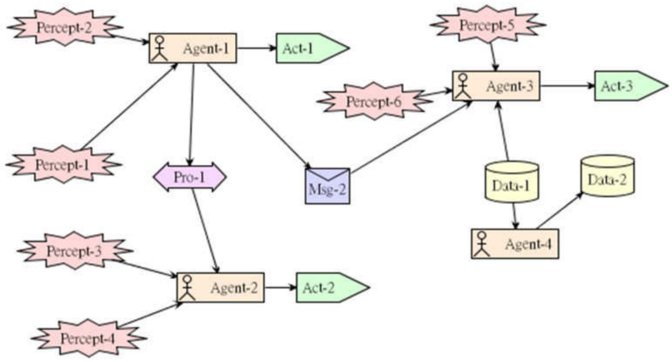


Fig. 3: Interactions of Intelligent Agent Society.

According to the mission and general goals of a component, the societies of agents develop sets with different level and features for different activities and special functions. From top down, the space in the building have different functions to accompany user's activities. The feature and user's activity determine the design goals of the agent and society, which then decide the mission, function, variables, and rules of the agent and group. However, from bottom up, the modes of variables and rules are developed to meet activity needs from the agent's point of view. From the agent society's point of view, they collaborate to accomplish missions of an activity (Figure 4).

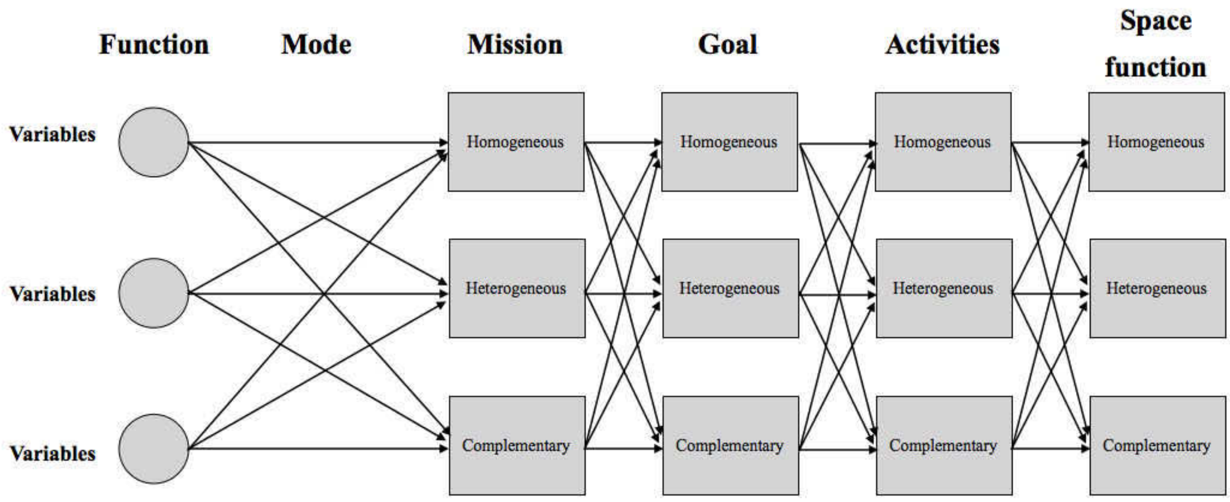


Fig. 4: Hierarchy.

There are three types of relationship for the agent function and space function: homogeneous, heterogeneous, and complimentary. For example, if the "space function" is set to be a study, targeting the "activity" of reading, the agent of the study must collaboratively complete the adjustment of lights and privacy ("goals"). Therefore, according to design "goals," each agent will be assigned a different "mission." The feature, activity, goal, mission, and function are viewed as sets in the discussion. The relationship between sets include: homogeneous, heterogeneous, and complementary. The logic operators "or, and, Xor, and not" are used to show those relationship (Figure 5) [5]

On the other hand, the intelligent agent and group theorem can also be applied to collaborative "smart living" design group (human and human). The space and building "designers" are the bridge between the home "user," "home industry" and "builder." To build an intelligent living space, the design group determines the smart home device, material, furniture, building components, facilities, and the relationship between overall allocation and space. It effectively contacts the smart home industry for information and new service regarding products, feature, function, and price. As a result, the visual stimulation of special design and budget are presented to the home user, fulfilling the agreement and needs for a smart living.

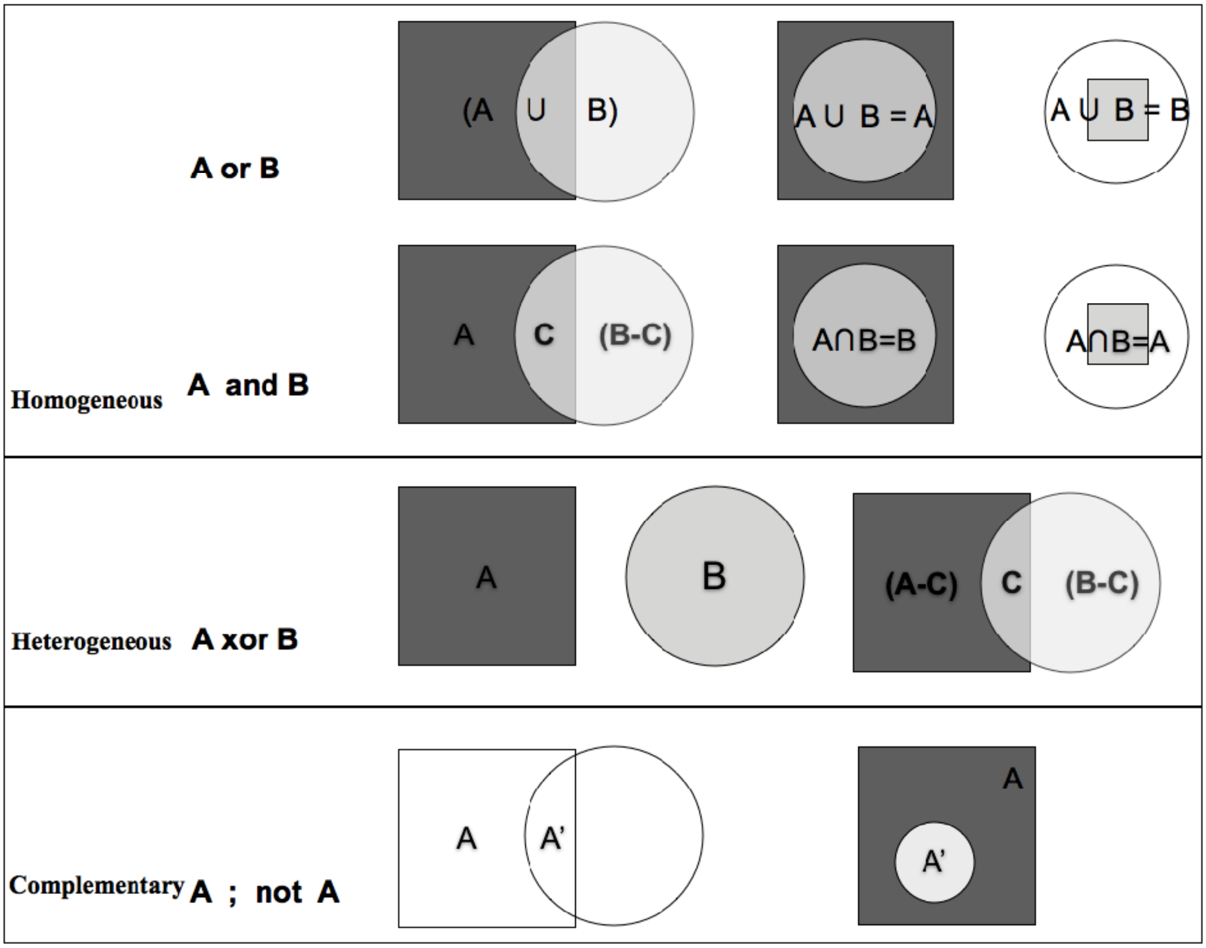


Fig. 5: Venn diagram.

3.2 Scenario-Orient design

"Scenario-Orient design is a new design for the product and service in the information era." [22]

The scenario-oriented design strengthened the intelligent agent theory regarding the function of space. As previously discussed, an intelligent agent is capable of interpreting "object and object," "human and human," and even "human and object" interactions. However, the information is not enough to create the space without the ability to describe and recreate, or merely concluded to the extent of special features. From top down, the "script" (scenario-oriented design) describes a "story," and the "story" is a combination of related "scenes." The "scenes" include a series of "activities" and the stage for such "activities" (the space and its background). The stage includes the space and allocation of furniture and objects in such space, both dynamic and static. The intelligent agent drives "events" from bottom up. A series of "events" satisfying the "missions" and "goals" support human and object "activities" on the "stage." Therefore, the "scenario-oriented design" and "intelligent agent theorem" work hand in hand. They "recreate knowledge" for the operation, computing and communication of human and objects in the space (Figure 6).

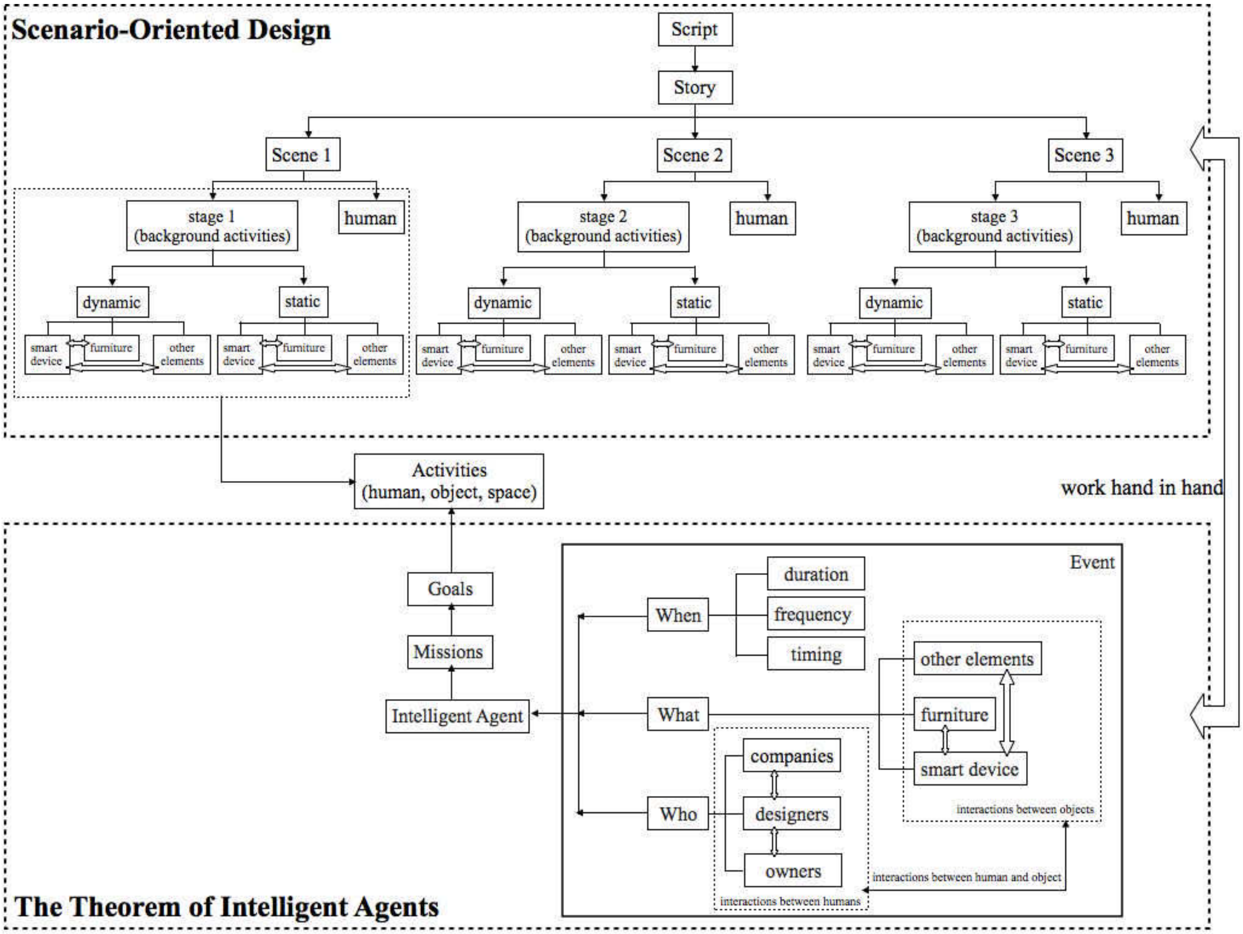
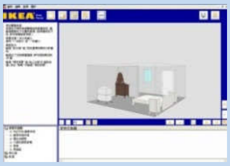
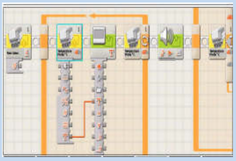


Fig. 6: Scenario-oriented design and the theorem of intelligent agents.

4 CASE STUDIES

The study on "computer-aided design interface for smart home device" is based on the above "studies on the trend of smart house," "cloud-computing and software service." The "intelligent agent theorem" and "scenario-oriented design" are the key factors in the theoretic framework. Next, we use the following examples to study the "computer-aided design interface for smart home device:" (1) IKEA indoor furniture selection and design software, [11] (2) SKETCHUP [20], (3) NXT Robotics Kit [16], and (4) HBE-UBI-Homenet [10]. The former two are platforms under cloud-computing environment and software service, while the latter two are specific software provided by companies to control agent-based products. The analysis include (1) elements of cloud-computing network environment and software service, (2) special design and visual simulation, (3) the mechanism and operation of intelligent agent, and (4) the control mode of smart home device (Table 3).

	IKEA Indoor Furniture Selection and Design Software	SKETCHUP	NXT Robotics Kit	HBE-UBI-Homenet
Image				
Introduction	The IKEA program can be downloaded and updated on the internet for free. The software visualizes the allocation of IKEA furniture and space; it also helps budget management. It helps home designers and allows companies to provide latest product information, communicate the design and costs.	SKETCHUP is free 3D design software provided by Google. It visualizes, stimulates the space and is easy to learn. By applying the digital "stretch" and simple "tool kit," computer space design becomes easier. SKETCHUP 6 supports the upload and download of "Google earth," and "3D Warehouse," encourages participants to communicate and design together on the internet. Many countries use it to build "digital cities" on Google earth.	The driver NXT-G is licensed software by LEGO. The object-oriented, modular, and graphic interface is easy to operate, making it easy to control robots. Users do not need professional programming skills. Users select sensors and motors, set conditions for the scenario, and input to the computer of the robot. The robot receives environmental information through sensors; the computer computes and makes judgments, driving the motors to finish the mission.	HBE-UBI-Homenet is the software to control smart home device. The interface allows users to control device in the home environment and access the status of home device. Remote control is accessible through internet and computer interface. The interface is easy to operate, but the pre-operation phase is complicated. Smart home device are first assembled, then users use custom or original executable files, which is compiled by Cygwin system software and then burn to the operators using AVR Studio.
Application	Simple indoor design, furniture allocation and purchase	Modeling, project design, collaborative design decision	To control robots	To control smart home device
Goals	Targeting the sales of IKEA furniture and help select furniture and space allocation	Digital design, collaborative design decision	The complex programming is replaced by simple graphic interface to promote the robotics industry and education	Promoting smart living space and its own products
Users	Indoor designer, Furniture salesman, Home user	Beginners in computer-aided design, Architecture or space designer	Beginners in robotics , Professional researcher	Users with information or communication background, Professional researcher
Steps	1. Draw the floor plan 2. Furniture allocation 3. 3D image	1. Download the base information of Google earth 2. Tool modeling	1. Outline the script for robot mission (action) 2. Build the physical	1. Assemble the suitable smart device 2. Open and compile the Cygwin system

	4. Lists of furniture and budget	3. Select material 4. Search for supporting units in "3D Warehouse" (like trees, cars, or people) 5. Light adjustment 6. Work completion 7. Upload the 3D work through Google earth to the base 8. Decision-making on the internet	model 3. Choose the motors and sensors according to the mission script 4. Set the conditions and details for each motor and sensor 5. Input the programs to NXT computer 6. Execute the file, test run 7. Success, or modify the programs or physical model if failed.	software 3. Link the smart home device, and burn the executable file to the operators using AVR Studio. 4. Link to the Zigbex server, repeat step 1 to 3 (compile and burn the executable file to the server) 5. Open the Homenet interface for operation
Feature	Cloud-computing software service; computer-aided design	Cloud-computing software service, computer-aided design	To control agent-based robots; the robots is capable of sensor, computation, and action, and communication	To control smart home device that is agent-based (including the sensor, microprocessors and motors
Advantage	Accessible operation, offering choices for furniture selection and price which satisfy the basic needs of furniture-purchasing consumers	Fast modeling, easy operation, the work can be uploaded to the internet by Google earth or 3D Warehouse, encouraging cooperative design	Graphical programming and easy operation; understands the operation of each components including the scenario-oriented design and logical thinking	Integrated intelligent device, wireless transmission control program
Constrain	Only provides IKEA furniture catalog, currently not open to other product information of affricated firms	Compared to other computer-aided software, SKETCHUP is limited in the modeling capacity (often produce squeezed shapes); the light shading is limited to "natural light"	No debugging inspection function, limited situational conditions; the interface is not suitable for complicated actions	Hard to operate and compile, the operating mode is fixed and not flexible to different scenarios, lack supporting design features
Trend	Open supporting framework, easy to obtain service information IKEA-affiliated companies with integrated design of smart home device and traditional furniture	Cloud-computing operating environment , design process, and collaborative design decisions	Human-computer interaction, scenario-oriented script, detailed settings, multi-robot cooperation model	Easier to operate, vivid designs targeting user's needs

Tab. 3: Case study on software.

According to the case study, under the service of cloud-computing software, renewable and free "computer-aided design software for smart home device" requires an open supporting framework and standardized communication platform. It will enable the intelligent industry to update product information and expand supports. It is supposed to be easy to operate and have modulated and objected oriented graphical user interface. The goal is to promote the cooperation and decision-making among the "designer," "industry," and "home user." This include situational needs of home user, the coordination of objects in the space, the technology of home device company, visual stimulation of space settings, and budgeting conditions. "Space designers" can thus provide professions service on smart living space design. As for the objects, the smart device, furniture and architecture elements shall be integrated in the space. As a result, the equipments and objects can coordinate, with the integration of sensor, computing, action, and communication techniques. They will react to environmental changes, the physical and mental changes of a user, and other activity needs.

5 SUMMARY AND CONCLUSIONS

Based on the "Evolution and trend of smart house" and analysis on modern "cloud-computing network development," the "designer-oriented" "computer-aided design interface for smart home device" is recommended. The "computer-aided design interface for smart home device" is based on the "scenario-oriented design" and "intelligent agent theory" as a tool of knowledge representation for the operation, computing, and information communication of the human and objects in the space. In the "case study," we explored the feasibility of theoretical applications. The advanced developments include (1) to construct the prototype for computer aided design interface for smart home device: the selection of smart home device technology, the goal and system analysis of interface, scenario analysis, the selection of multiple agents (technology/company), visual stimulation of space settings, and budgeting conditions. (2) The physical construction and tests of smart space: basic conditions for space settings (the size, scale, shape, opening, and physical condition of space), network set up and communication protocols, installation of furniture and home appliance, the allocation and installation of smart home device, and the operation and test. (3) Application and analysis: the feasibility and difference between the theoretical framework and practice, user feedbacks and opinions, and the feasibility of customized, special or derivative applications (Figure 7).

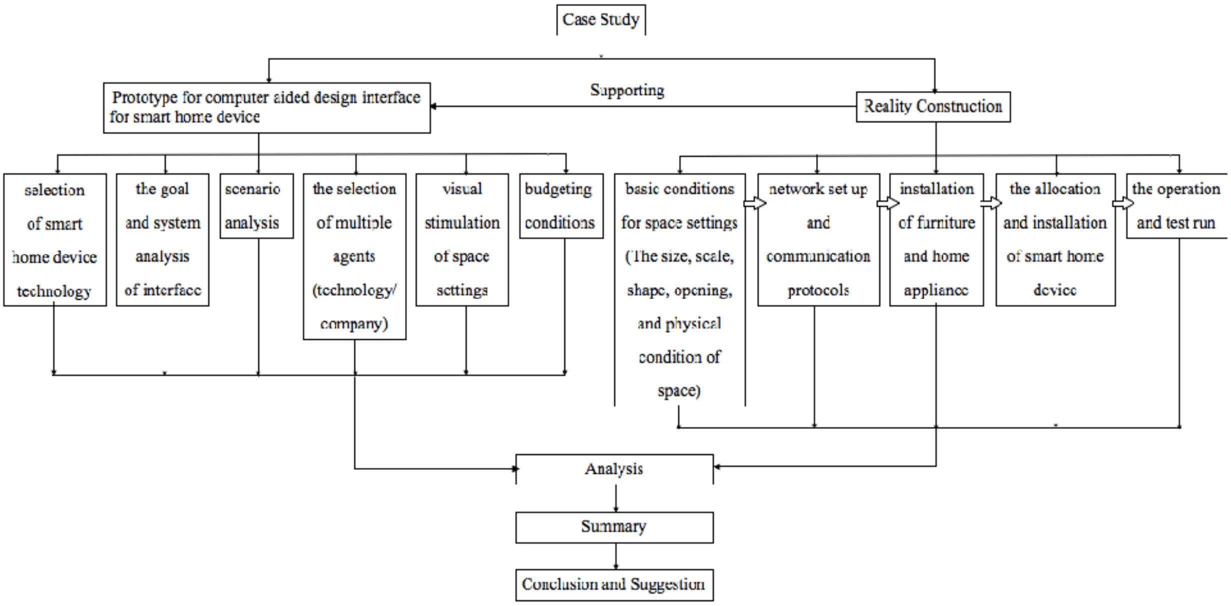


Fig. 7: Advanced developments and steps.

The goal of "computer-aided design interface for smart home device" is to promote the communication and cooperation among the "designer," "industry," and "home user," in order to reach better decisions. As for the objects, the smart device, furniture and architecture elements shall be integrated in the space. As a result, the equipments and objects can coordinate, with the integration of sensor, computing, action, and communication techniques. It also responses to environmental changes, changes user's the physical or mental conditions, and other needs. Figure 8 presents the stimulation of the "computer aided design interface for smart home device."

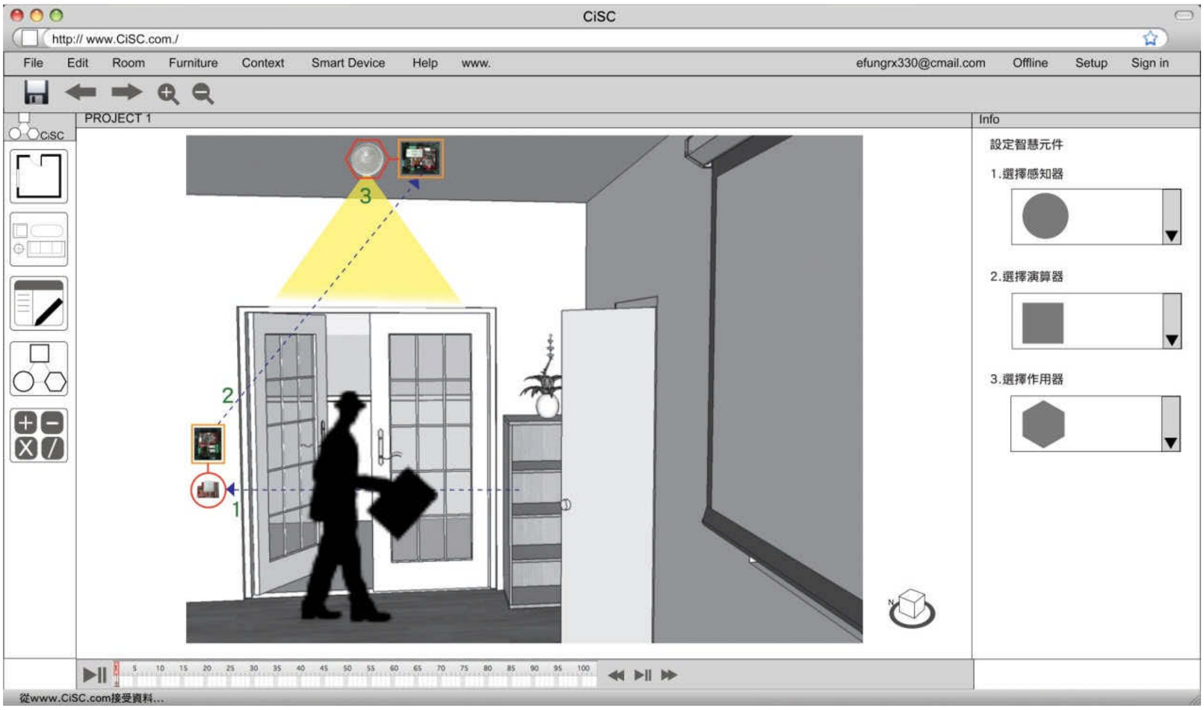


Fig. 8: Stimulation for the "Computer Aided Design Interface for Smart Home Device".

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