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A Review of Smart Living Space Development in a Cloud Computing Network Environment

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ABSTRACT

Recent advances in computer and communication technologies have offered people unprecedented levels of convenience, comfortable, and enjoyment. To allow occupants to better perform their daily living activities, improve the quality of their lives, and enjoy entertainment and leisure activities, one must first understand the services that occupants need in smart living environments, and then develop key technologies to support such needs. This paper focuses on emerging smart technologies, innovative design solutions, and smart material for smart living spaces in a cloud computing network environment.

Keywords: smart technology, smart design, smart material, cloud computing.
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1. MOTIVATION AND GOALS

The development of Taiwan's ICT industry is creating growing opportunities for the emergence of a "smart living space" industry. This study proposes that the three basic elements of smart living spaces are: (1) smart technology, (2) smart materials, and (3) smart design. These elements form the basic framework for the classification of smart living spaces. This study also discusses the constituent elements and functions needed by smart living spaces in a distributed cloud computing environment so as to achieve the user-oriented goals of (1) safety and security, (2) health care, and (3) convenient and comfort, and the environment-oriented goal of (4) sustainability and energy conservation (Fig. 1) The various chapters and sections of this paper cover the following items:

2. LITERATURE RETROSPECTIVE

In a cloud computing network environment, the main challenge is how to manage, connect, and coordinate smart residential elements in a cloud computing environment so as to achieve specific tasks. This paper analyzes the three top-down technical levels of (a) basic facilities, (b) platform, and (c) applications. Cloud computing, where applications and files are hosted on a “cloud” consisting of thousands of computers and servers, all link together and accessible via the internet, is web based instead of desktop based. Users can access all their programs and documents from any computer that’s connected to the internet. Cloud computing emphasizes "the network is the computer"; its applications and services construct and link together the basic units of "smart residential components" to form a ubiquitous computing environment. Here cloud computing involves residential elements and their tasks, a user interface, system management, provisioning services, cloud servers, and Web applications. [12].

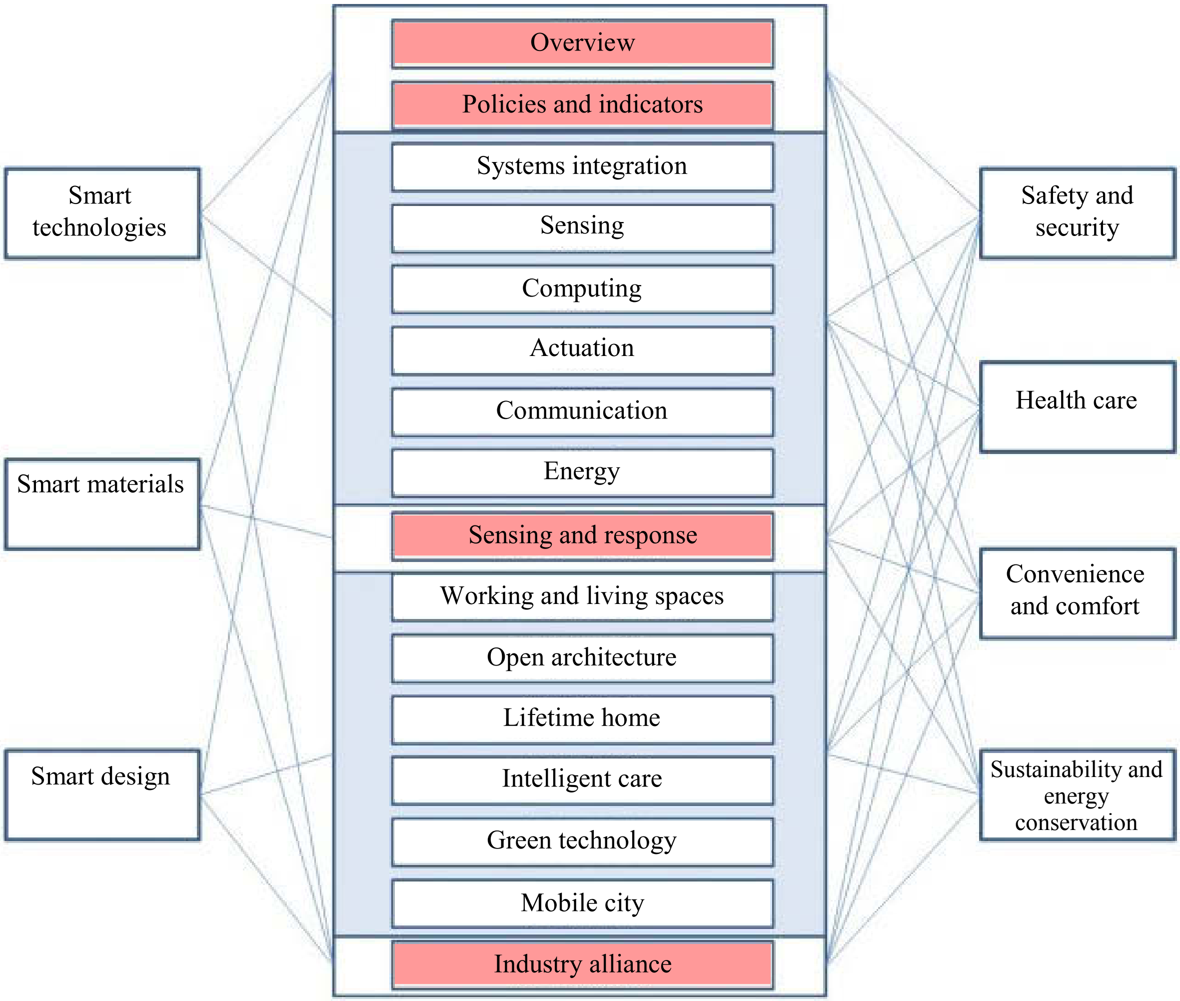


Fig. 1: Network architecture of smart living spaces.

From the angle of "intelligent agents," this paper lists the bottom-up elements of (a) perception, (b) computing, (c) actuation, (d) communication, and (e) energy as bases for the development of residential technology. Chiu (2005) proposed that the three key functions of a smart home are (1) a smart skin, (2) a smart living, and (3) smart care [1]. These functions employ methods such as (1) smart materials, (2) smart technology, and (3) smart design to achieve smart environment design goals (Fig. 2). Taking a smart skin as an example, the author's doctoral dissertation "The Study of Applying agent-based theory to adaptive architectural environment - Smart skins as an example " presents a theoretical framework for the foregoing intelligent house concept. That study employed intelligent agent theory to establish an intelligent architectural environment possessing the attributes of sensory - computing - actuation (PCA), which is to say that it possesses context awareness. This architectural environment's computing mechanism can take into consideration various kinds of situations, and its driving building components can bring about adaptive effects [2]. Nevertheless, apart from computing technology, recent smart architecture has mainly focused on the effect of networks, and has chiefly investigated applications in small scale living spaces. In other words, new models require greater application of communication capabilities in order to establish smart living environments with sensory - computing - actuation - communication (PCAC) capabilities.

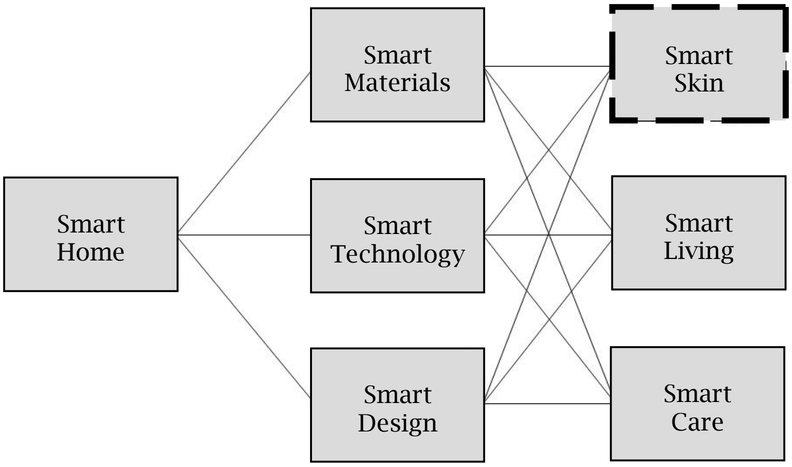


Fig. 2: A smart home framework, (Chiu, 2005).

"A smart home can be defined as a residence equipped with computing and information technology which anticipates and responds to the needs of the occupants, working to promote their comfort, convenience, security and entertainment through the management of technology within the home and connections to the world beyond [4]*."* The development of automated houses based on artificial intelligence applications is no longer a novel idea. Nowadays automated factories, power plants, remote equipment, shopping centers, high-rise buildings, and other large and complex architectural applications have sprouted up in many places. Architectural automation can strengthen safety, reduce accidents, save money, and operate existing equipment and facilities. Because smart technology is effective and possesses many commercial uses, it is commonly incorporated in large buildings and facilities. On the other hand, the implementation of smart technology in homes is quite difficult. The occupants of a home typically want to enjoy convenient and comfortable lives, but are not necessarily concerned about economic effectiveness or the effective operation of equipment or facilities.

"Following the electrification of homes in the early 20th century, this clean and convenient form of energy, along with its products and peripheral applications, initiated a revolution in residential technology." "Advanced home control systems have many names, including smart homes, home automation, and integrated home systems. These names all signify the convenient control of household appliances and peripheral equipment, including video players and recorders, intercoms, security systems, lighting, air conditioning, and sprinklers. Users can employ a network to remotely determine how much power is being used and what types of appliances are currently in use. Furthermore, the use of remote controllers (such as telephones of computers) allows residents to turn on air conditioning, etc. Because of this, homes and workplaces will become better connected [23]." Since the end of the 20th century, the incorporation of information technology and communications technology – particularly networks – in homes has been widely investigated.

A look at academic and practical efforts is sufficient to summarize major research directions in the field of intelligent houses. Intelligent house research chiefly pursued home automation from the 1960s to 1980s, and the adoption of information systems and implementation of intelligent controls in the 1980s and 1990s. Work since 1995 has chiefly focused on smart environments possessing ubiquitous computing. The nature of controls has shifted from the past quantitative methods to minimum energy consumption and maximum user comfort, and eventually to today's combination of sensing technology, computing technology, and information and communications technology in order to bring about self-programming ability better able to reflect users' living habits [13]. The past central control model yielded zone and dispersed control mechanisms [9]. The development of intelligent houses is not just an academic matter, of course, but has involved mutual testing via practical applications.

With regard to academic research, Dard (1996) focused on household activities and flows (flow of people, energy, and information) [6]. Barlow (1998) chiefly investigated technology and proposed three use levels: (1) Universal technology for use in more precise systems, (2) context-specific systems for use in different types of buildings, and (3) individualized systems suitable for the needs of individuals and housewives [5]. Gann et al. (1999) emphasized the practicality of functions to users, and recognized two types of intelligent houses: One type is defined as a house containing conventional home automation, and using intelligent appliances. The second type involves information sharing and interconnected computing, which can give homes functions transcending those of conventional households [7]. Jedamzik (2001) suggested that smart houses possess four elements: (1) user interfaces, (2) a technological domain, (3) and information domain, and (4) a service domain [8].

With regard to practical applications, the 1960's saw attempts to create wire-control homes. Commercial applications of home automation began appearing in the 1980s. The development of power and appliance digital systems and elements intended for the home started around this time. Other intelligent house items developed during this period involved construction, power, architecture, energy-conservation, and telecommunications. The following four major automation indicators of intelligent buildings emerge during the 1980s: (1) building automation, (2) office automation, (3) communications automation, and (4) architectural and environmental integration [16]. Furthermore, the emergence of the "pocket office" concept indirectly promoted the development of intelligent houses. By the 1990s, the intelligent house concept had invaded mass culture and the media together with the idea of "ubiquitous computing." Smart technology began flooding into residential living from this time on. For instance, ITRI. (2007) the preliminary integration of digital security monitoring systems in smart living spaces has involved the use of various sensors to constantly monitor changes in the living environment, detect any outside intrusion, check whether there are any problems such as gas leaks; furthermore, such systems can also include indoor positioning systems, home remote medical monitoring and care systems, medication reminders, and online household appliance controls. Taiwan's Architecture & Building Research Institute, MOI has commissioned the Material and Chemical Research Laboratories, ITRI to implement such a system. The government's smart living spaces program emphasizes the four major topics of safety, health care, sustainability & energy conservation, and convenience & comfort, which will be gradually realized in practical applications [15].

3. CASE ANALYSIS

There are in fact relatively few smart houses that actually apply smart technologies. One reason for this is that, apart from communications, control, and entertainment, residential and living spaces have more complex and varied design goals. This study has selected the following well-known cases as the basis for a qualitative analysis of smart houses. These houses are classified as either "academic," consisting of laboratories possessing residential functions and model homes (Tab. 1), and "practical," consisting of actual houses, clustered housing, and other practical market products that can be used on a daily basis (Tab. 2).

To summarize the foregoing research, in the academic sphere, researchers have realized (1) computing models, (2) control interfaces and integration systems, (3) user-oriented context awareness systems, and (4) architectural design and building systems in a ubiquitous computing environment, achieve theoretical and technological innovations and conditional restrictions. As far as practical applications are concerned, builders and designers emphasize the realization of the life goals of smart houses, and are using already-developed (1) basic equipment, (2) platforms, and (3) applications to design smart skins, smart living, and smart care functions. These projects are realizing the user-oriented life goals of (1) safety and security, (2) health care, and (3) convenience & comfort, as well as the environmentally-oriented goal of (4) sustainability & energy conservation. Nevertheless, with regard to energy and resource applications, the goals of user-oriented smart living and environmentally-oriented sustainability & energy conservation are not necessarily consistent. Only when renewal green energy used can occupants truly enjoy smart living with safety and health care.

Case	Adaptive House [18]	Intelligent Working Space [10]	The Aware House [19]	Sentient Buildings [11]	Toyota's Dream House [14],[25]
Year	1997	1997	2000	2004	2004
Image					
Designer	Mozer, M.C.	Lam, K. P.	Aldrich, F. K.	Mahdavi, A.	Sakamura, A. K.
Location	Boulder, Colorado, USA	Roof of Architecture Department building, Carnegie Mellon University, Pittsburgh, USA	Georgia Tech, Atlanta, USA	Department of Building Physics and Building Ecology, Vienna University of Technology, Vienna, Austria	Toyota City, Aichi Prefecture, Japan
Function	Personal home of researcher	Instructors, employees, graduate students	Dispersed family members, elderly persons	Instructors, employees, graduate students	Family residents
Goal	A self-programmable home: An automated house that can change with changes in the users' lifestyles.	1. The state of the house is continuously adjusted to pursue "user comfort" and "energy conservation." 2. House diagnosis, preventive maintenance, and system operation decision-making	1. Applies sensing technology, a network, and information & communications technology to connect family members dwelling separately. 2. Helps the elderly live at home for as long as possible and maximizes independent living ability.	Context awareness: dynamic adjustment of building environmental conditions in keeping with user needs.	Optimal control of smart devices in an intelligent environment with ubiquitous computing.

Key technologies and design principles	1. Establishment of the self-programming ACHE adaptive dwelling control system. 2. Use of sensors to track users' movements. 3. Unsupervised Q-learning reinforcement learning optimized control. 4. Lamps are controlled in keeping with user activity.	1. Uses a "sensing information system" and "energy monitor" to create a dynamic building information model. 2. Collects house life cycle data in order to assess (IW) performance. 3. Uses network capabilities to perform remote monitoring.	1. Dwelling awareness technology. 2. Software automatically establishes members' portraits, voice control system, remote control, reminders, and alarm devices.	1. Represents a self-updating and maintaining dynamic model to application buildings and users. 2. Uses a network to achieve remote control of building life cycle products and processes via an information interface.	1. Uses pervasive communicators as a basic intelligent model combining awareness, computing, and communication 2. An industrially manufactured pre-cast house incorporating smart control and operational maintenance.
Trend research	Explores machine learning: ability to infer user activities and characteristics	1. Confirmation of data reliability and sensor calibration. 2. Diagnosis and identification of possible malfunctions. 3. Active learning and adaptation.	1. Ongoing study of four major topics: human-centered, technology, software engineering, and social implications. 2. Context-aware computing. 3. Individualized health equipment.	Uses information model technology to implement environmental monitoring, local sensing, spatial inferences, performance simulations, and basic model control logic.	Intelligent house, intelligent environment can be expanded as far as a future city.

Tab. 1: Qualitative Analysis of Academic Smart Living Spaces.

Case	e-House2000 [21]	House R128 [22]	Valley Center House [27]	Living Glass [24]	Crystal House [20]
Year	2000	2000	2000	2008	2009
Image					
Designer	McDonough, M	Ingenieure, W. S.	Genik, D.	Soo-in Yang, S. I.	Hung, H. Y.
Location	New York, USA	Stuttgart, Germany	Mt. Palomar, California, USA	Building's Skin	Taichung, Taiwan
Function	Three rooms and two lobbies, work/dwelling	A four-story mountain house	A one-story mountain house	A smart skin prototype	High-rise clustered housing

Goal	Sustainability & energy conservation, convenience & comfort	Sustainability & energy conservation, energy self-sufficiency	Application of smart design and materials	Smart materials, health care	Safety, health care, sustainability & energy conservation, convenience & comfort
Key technologies and design principles	A building applying 3D software design passive principles and optimizing energy efficiency. Uses the Internet to integrate already-developed green energy technology, sensors, and software, and employs actively driven adaptive elements to maintain a comfortable environment.	Emphasizes zero carbon emissions during the construction process; modular design employs steel members and pre-stressed floor slabs. The roof is equipped with solar panels achieving energy self-sufficiency in conjunction with a connection to public power. Employs dwelling control software to control household appliances under different circumstances.	Employs reflective aluminum sun visors. Apart from effectively blocking the sun, the house also permits indirect reflected light to enter the house during hot weather, keeping the interior well-lit. Indoor light shines outside during the nighttime. The panels are adjustable; their height can be changed or their vertical surfaces adjusted to create different openings.	Openings in the skin are adjusted in accordance with CO2 concentration.	An extension of the 1990s' pocket office, this building incorporates BA, OA, CA, AE automated equipment in high-price clustered housing. An innovative SI network includes three-in-one (telephone, Internet, video) integrated wiring system, and a FTTH community fiber-optic network. Users can employ a Web interface or wireless remote controller to inspect environmental information, control usage, or turn on HA applications.
Trend research	Intelligence focuses on the pursuit of optimal energy efficiency.	Intelligence is incident driven; users can employ a touch-control panel to control the house under specific circumstances.	Intelligence is reflected in material use. Adaptive design is reflected in openings and activities.	Intelligence is reflected in changes in materials; changes are closely connected with residents' health.	Intelligence is reflected in user safety, health, convenience, environmental sustainability, and energy conservation.

Tab. 2: Qualitative Analysis of Practical Smart Living Spaces.

4. THEORETICAL FRAMEWORK

According to the foregoing literature retrospective and case analysis, it is recommended that the three basic elements of (1) smart technology, (2) smart materials, and (3) smart design be used has a basic framework for the classification of smart living spaces and analysis of smart living elements and functions so as to achieve the life goals of (1) safety and security, (2) healthcare, (3) sustainability & (4) energy conservation, and convenience & comfort. The three basic elements are discussed as follows:

4.1 Smart Technology

Sensing and communications technology, artificial intelligence computing technology, and autonomous control methods can be used to achieve design objectives.

(1) Top-down integration can employ a network-based smart environment. The top-down framework includes the three technological levels of (A) infrastructure, (B) platforms, and (C) applications (Tab. 3).

Level	Content
Infrastructure	Global and municipal infrastructure (provided by network equipment companies such as Cisco and operating firms such as Chunghwa Telecom)
Platforms	Include hardware and software platforms (software/hardware platforms provided by Microsoft, Apple, etc., smart dwelling architectural elements)
Applications	Include mail, real-time communications, community information, personal health, and care information, etc.

Tab. 3: Levels and their content.

(2) With regard to bottom-up classification, in a distributed computing environment, smart architectural elements can be seen as independent intelligent agents. These elements may include (A) sensory, (B) computing, (C) action, (D) communications, and (E) energy elements (Tab. 4).

Element	Content
Sensory	Environmental sensation factors, sensors and their distribution and density, and sensor action times, duration, and interrupt times. (1) Various sensors: measurement of interior environment of building (light, sound, heat, air, water); measurement of users' physical attributes (location, speed, acceleration, posture, job, gender), invasive physiological attributes (blood, genes), and non-invasive physiological attributes (heart rate, pulse, blood pressure, temperature), and forecasting of users' psychological states (pleasure, anger, sadness, happiness). (2) Multiple factor monitoring technology. (3) A multi-person, multiplex input platform. (4) User-friendly communication format.
Computing	Selects an algorithm according to the circumstances, provides a mediation mechanism capable of comparing signals and adjusting their magnitudes. (1) Artificial intelligence: rule-based, neural network, fuzzy logic, agents. (2) Distributed computing: ubiquitous computing, grid computing, cloud computing. (3) Middleware: dwelling control software. (4) Human experience computing. (5) Prediction algorithms. (6) Location estimation. (7) Automated decision-making. (8) Security, privacy, and trust.

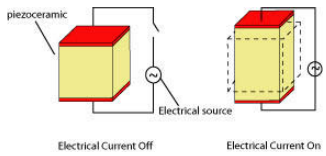
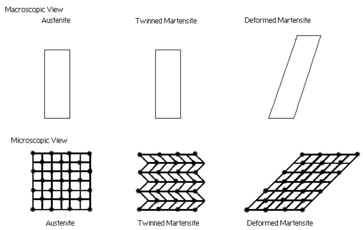
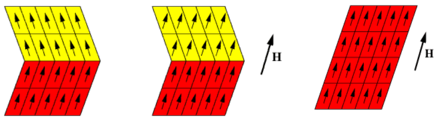
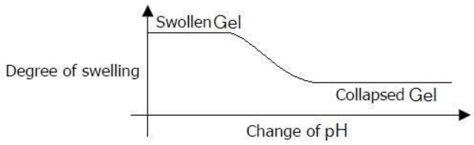
Actuation	Integration of smart appliances and personal equipment in an intelligent house; discussion of possibility of multimedia output. Research and development. (1) Adaptive smart architectural elements and corresponding situations: architectural controls and response elements and systems corresponding to internal environmental factors (temperature, humidity, illumination, chemicals in air) and users' physiological comfort and psychological responses (pleasure, anger, sadness, happiness). (2) RFID applications. (3) Portfolio equipment. (4) Home appliances. (5) Multimedia display. (6) Global positioning system.
Communication	Form of communication between Intelligent agents, smart objects, users, and personal accessories; existing standard communication protocols. (1) IPv4 and IPv6 communication protocols. (2) Interface design. (3) Power line communications technology. (4) Wireless communications and pervasive technology: WiMAX, WiFi, Zigbee, Bluetooth, etc. (5) Home networking: group and level settings (including function, model, mission, objective, use activity and spatial function settings).
Energy	The greenhouse effect and global energy crisis have made energy conservation and carbon reduction essential functions. Sustainability is often at odds with energy-consuming smart living technology and applications, however. Only the development and application of green energy technology can enable us to safely enjoy smart living. (1) Types of green energy: solar power, wind power, hydropower, geothermal energy, biomass energy, fusion. (2) Green energy selection and assessment factors: objective conditions such as ease of obtaining materials, influence of weather, site restrictions, production technology threshold, and unit cost. (3) Green energy applications: AC power systems, DC power systems, parallel connections to municipal power, independent island-type power systems.

Tab. 4: Elements and their content.

4.2 Smart Materials

Materials with environmental sensing ability and responsiveness can change their state according to control signals or stimuli. Control signals and stimuli include pressure, temperature, humidity, pH, power, and magnetic fields. Responses include changes in shape, color, density, and phase. Addington (2005) classified smart materials as two types; one type is property changing, and the other is energy exchanging. The conditions and restrictions that apply when these two types are used as building materials require further investigation [3]. Table 5 lists several types of known smart materials, along with their stimuli and responses [26].

Material	Stimuli	Response	Principles

Piezoelectric materials	Voltage	Shape change	The application pressure to a piezoelectric material will produce a voltage, and the application of a voltage will cause the material to expand. Can be used in applications where the material changes shape when an electrical current is applied. 
Shape memory alloys and shape memory polymers	Temperature	Shape change	Shape memory alloys and shape memory polymers are thermo-sensitive materials that undergo shape change when the temperature changes. One type of shape change occurs when a low-temperature, relatively soft martensite phase changes to a high-temperature, relatively hard austenite phase. The figure on the left is an austenite sample, and the central figure is a ”unitary shape change martensite" sample; at this time the internal structure has changed, but the external shape is still unchanged. 
Magnetic shape memory alloys	Magnetism	Shape change	Magnetic shape memory alloys undergo large-scale reversible shape change when a magnetic field is applied. While these materials are generally similar to temperature shape memory alloys, a magnetic field will cause an austenite phase to change to a martensite phase. Compared with temperature, a magnetic field can provide a faster response time. 
pH-sensitive polymers	pH	Shape change	pH-sensitive polymers swell or collapse when the ambient pH changes. These materials are usually applied in drug delivery systems. 

Temperature-responsive polymers	Temperature	Hydrophobicity	Temperature-responsive polymers exhibit changes in hydrophilicity and hydrophobicity in response to temperature variations.
Halochromic materials	pH	color	Halochromic materials change color under the influence of pH changes. These materials are commonly used to test whether metal has suffered corrosion. Their color changes are due to differences in the absorption of light caused by changes to hydrogen bonds.
Chromogenic systems	Electrical, brightness, temperature	Color, transparency	Chromogenic materials change color under the influence of electrical, brightness, or temperature changes. For instance, some optoelectronic materials will change their color or transparency (such as liquid crystal glass) when a voltage is applied. For example, thermal chromogenic materials change color after the temperature changes. Light-sensitive chromogenic materials, such as the glass in some sunglasses, change color when the illumination changes.
Non-Newtonian fluids	External force	Viscosity, Appearance	Non-Newtonian fluids refer to liquids that can change their viscosity in response to an applied shear rate. In other words, the application of pressure to these liquids will briefly change them to solids.

Tab. 5: Stimuli and responses of smart materials.

4.3 Smart Design

Smart design involves the innovative conceptualization and integration of the environment, users, space, shapes, smart technology, materials, and technologies (Tab. 6).

Issues	Summary
From an intelligent working environment to intelligent living spaces	Starting around 1970, the application of artificial intelligence paved the way for building automation. Building automation is efficiency-oriented; today, BA, OA, CA, and AE are well-developed fields. Since 1900, the use of networks has enabled HA – "home automation" – to emerge. Home automation is convenience-oriented, and chiefly focuses on small-scale dwelling unit applications. Municipal-level Chunghwa Telecom's deployment of a three-in-one cable and fiber optic network framework in 2006 and the emergence of "cloud computing" worldwide since 2008 have set the stage for the gradual development and maturation of smart living spaces.
Adaptive open architecture	Traditional static buildings are composed of fixed elements, and cannot respond to transient, dynamic environmental changes. Although a theoretical basis has been established for variation in open architectural systems, open architecture lacking smart mechanisms cannot sense external changes, and cannot actively determine the optimal moments for changes in architectural element, and thereby implement adaptive optimization programs. Because of this, adaptive open architecture applying artificial intelligence to bring about adaptive changes must be developed in order to meet the needs of sustainable development while providing users with a comfortable living environment.
Context aware lifelong home	Responding to the aging of society, context aware lifelong homes have been proposed as a means of meeting basic sustainability and health needs. These homes employ sensing, computing, and information & communications technology, and combine adaptive architectural elements with context awareness functions enabling optimal response to user needs and environmental changes. These homes can allow the mobility-impaired and the elderly to lead maximally independent lives, and feature incident-driven general-purpose designs.
Smart care	Demographic aging and smaller families are changing the form of contemporary families. Parents no longer feel that they must raise many children to obtain support in old age. Furthermore, the

	emergence of families with two breadwinners has made home care very difficult to manage. As a result, at-home service is a growing trend, and there is a need to develop technology aimed at improving the well-being of the elderly. The provision of distance residential care and input from the ICT industry can meet the need for active care and enable elderly persons to enjoy the greatest possible independence.
Green buildings	The greenhouse effect and global energy crisis have made energy conservation and carbon reduction essential functions. Sustainability is often at odds with energy-consuming smart living technology and applications, however. Only the development and application of green energy technology can enable us to safely enjoy smart living.
Mobile cities	Computer graphics, virtual reality, photographic surveying, satellite images, geographical information systems, and satellite positioning systems are providing new ways of visualizing urban areas. Network technology is also offering many ways to integrate urban information. Portable equipment will allow users to use this information to find directions and perform navigation. In the area of virtual travel, different interactive functions will provide entirely new urban impressions.
Industry alliances	The construction of a full-scale intelligent living environment will involve the development of intelligent cities, communities, buildings, and homes. In addition, the building lifecycle viewpoint – which encompasses the stages of smart dwelling design, construction, use, maintenance, renovation, and recycling – will involve collaboration between architectural research, building design, construction, information & communications, micro-electromechanical integration, electronics, electrical machinery, safety and disaster prevention, sustainability & energy conservation, and health care organizations and industries, as well as the mutual cooperation of industry, government, and academia.

Tab. 6: Smart design issues.

The following smart living space dimensions, issues, elements, and life goals are listed in accordance with the foregoing framework and summary (Tab. 7).

Dimensions	Issues	Elements and keywords	Life goals			
			Safety and security	Health care	Convenience & comfort	Sustainability & energy conservation
Summary	Smart dwelling life elements	Smart cities, communities, buildings, and homes; smart technology, materials, and design	*	*	*	*
	Policies, indicators	Development of smart building assessment indicators and smart living space policies				
Smart technology	Systems integration	Infrastructure, platforms, applications	*		*	*
	Sensing	Measurement, prediction, and control of health, environmental factors, and user status	*	*	*	
	Computing	Artificial intelligence applications, distributed computing environment, grid computing, cloud computing	*	*	*	

	Action	Smart architectural elements, smart household appliances, furniture design	*	*	*	
	Communications	Wireless communications and ubiquitous computing technologies, dwelling area domain group and level settings, IPv6 communication protocols	*	*	*	
	Energy	Types of alternative green energy sources, assessment and application				*
Smart materials	Sensing, response		*	*	*	
Smart design	From an intelligent working environment to intelligent living spaces	Building automation (BA, OA, CA, SA, AE), home automation (HA), home automation control systems, ubiquitous computing, cloud computing	*	*	*	
	Adaptive open architecture	Adaptation, adjustment, flexibility, open architecture, support and infill, intelligent agents, group and level	*	*	*	
	Context aware lifelong home	Context awareness, lifelong home, general-purpose design, the mobility-impaired and the elderly	*	*	*	*
	Smart care	Elderly welfare technology, distance residential care technology, ICT applications	*	*	*	
	Green buildings	Passive design, active equipment, green energy, green building indicators, comfortable environment	*	*		*
	Mobile cities	Computer graphics, virtual reality, photographic surveying technology, satellite images, geographical information system, and satellite positioning systems	*		*	*
Conclusions	Industry alliances	Architectural research, building design, construction, information & communications, micro-electromechanical integration, electronics & electrical machinery, safety & disaster prevention, sustainability & energy conservation, health care	*	*	*	*

Tab. 7: Smart living space dimensions, issues, elements, and life goals.

5. RECOMMENDATIONS AND DISCUSSION

The rapid development of Taiwan's information and communications industry has provided the country with an increasingly good opportunity to develop a smart living space industry. In view of Taiwan's current situation, (1) with regard to infrastructure, wireless communications technologies such as WiMAX, WiFi, 3G, PHS, and Zigbee [28] are realizing the prospect of ubiquitous information. Chunghwa Telecom has deployed a three-in-one (telephone, Internet, video) integrated wiring system, and the establishment of fiber-optic networks has smashed bandwidth restrictions. The IPv6 communication protocol uses 128-bit addresses and fixed-address Internet nodes; this protocol will be used for mobile devices such as PDAs and cell phones, and even electronics products such as music players and wrist watches. When the time comes, most of these increasingly ubiquitous products will have unique IP addresses, and will be able to obtain information or perform remote control tasks via the Internet. (2) With regard to platforms, the Google-inspired software + service (S+S) concept is providing increasingly diverse free software, which will make information applications even more commonplace and widely shared [17]. As far as hardware is concerned, the growing numbers of inexpensive computers and personal micro-computing equipment will achieve even greater functionality as long as they can connect to the Internet. (3) With regard to applications, online games, Gmail, Face-book, YouTube, and Web2.0 blogs are putting cloud computing theories into practice. Furthermore, portable personal computing tools have already become personal communications, control, and entertainment centers. Nevertheless, does the maturity of the information and communications industry imply that the smart living space concept has already become ubiquitous, and is already accepted and appreciated by industry and users? Compared with past revolutions in dwelling technology, his contemporary technology truly convenient and comfortable? Is industry actually prepared to integrate the most up-to-date technologies? This study relies on a literature retrospective and case analysis to perform assessment and discussion, and has constructed a theoretical framework for smart living spaces. This framework can provide a guide for subsequent research.

6. ACKNOWLEDGEMENT

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