Leveraging Human-Centric Computing to Enable and Support a Resilient, Prosperous, and Sustainable "Human-Centric Intelligent Society": Underlying Concepts and Highlight Technologies

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Abstract -Accelerated globalization has led to an alarming rise in increasingly intertwined, complex and daunting global-scale societal issues that significantly and directly impact people's lives worldwide – including energy, the environment/natural disasters, transportation/other vital infrastructures, population: explosive growth vs. aging societies, food/water supply, massive data security/management, etc. Simultaneously, continuous widespread expansion of practical-use ICT, along with continuous and explosive growth of massive data in society – in particular the advent of cloud computing and big data – have given emergence to opportunities and needs for ICT to provide "human-centric solutions" to handle such societal issues.

This conceptual paper provides an overview of how we foresee Human-Centric Computing (HCC) technologies as vital frameworks that will drive and provide much of the essential and practical means for enabling and supporting a resilient, prosperous, and sustainable "human-centric intelligent society" we envision for the future. We introduce some key underlying concepts pertaining to HCC, and highlight some relevant leading-edge HCC technologies that we envision will enable and support such a human-centric intelligent society.

(Note: This conceptual paper is based on a Keynote Speech delivered by Tatsuo Tomita, president of Fujitsu Laboratories Ltd., at the International Workshop on Informatics: IWIN 2012 held in Chamonix-Mont-Blanc, France).

Keywords: human-centric computing technologies, human-centric intelligent society, resilient prosperous sustainable society, big data, cloud computing, tailored services

1 INTRODUCTION

Against the backdrop of accelerated and continuous globalization in numerous realms of society and across a multitude of regions worldwide, there has also been an alarming rise in increasingly intertwined and complex global-scale societal issues – including energy, environmental sustainability, natural disaster preparation and recovery, population: explosive growth versus aging societies, data security and management, healthcare, food and water supply, transportation infrastructures, and financial data/system management sustainability, as some key critical issues impacting societies in both industrialized and developing nations.

Simultaneously, the continuous widespread expansion of practical-use leading-edge information and communication technology (ICT) along with continuous and explosive growth of massive data in society – in particular the advent and leveraging of cloud computing and big data – have given emergence to opportunities and needs for ICT to provide "human-centric solutions" to handle such globally intertwined, complex and daunting societal issues.

ICT – in particular Human-Centric Computing (HCC) technologies [1] – can and must play a stronger and more flexible comprehensive role toward enabling and supporting a resilient, prosperous, and sustainable "human-centric-" – not "technologic-centric-" – "intelligent society".

We foresee that HCC technologies as vital frameworks will drive the shift toward, and provide much of the essential and practical means for enabling and supporting a resilient, prosperous, and sustainable "human-centric intelligent society" [2] we envision for the future.

2 HUMAN-CENTRIC COMPUTING: CONCEPTS

2.1 Shift in Dynamics Between People and ICT

When envisioning a human-centric intelligent society supported by HCC, one important aspect to acknowledge is the shift in dynamics between people and ICT that has been occurring, and which we foresee will continue to occur – in the past, many intellectual activities conducted by people were often executed individually with few or no relations with each other's activities (Fig. 1).

Much ICT of the past focused primarily on automation to eliminate the need for human labor for certain tasks, and in that "technology-centric" era, it was necessary for people to adapt to ICT, rather than the ideal vice-versa. To some extent, currently this is still the case for some aspects of ICT.

However, as we see societies transition from a "technology-centric" to a "human-centric" era, we can observe that ICT will increasingly be developed from a "human-centric perspective", in accordance with people's and societies' needs.

2.2 Human-Centric Computing: Key Underlying Concepts

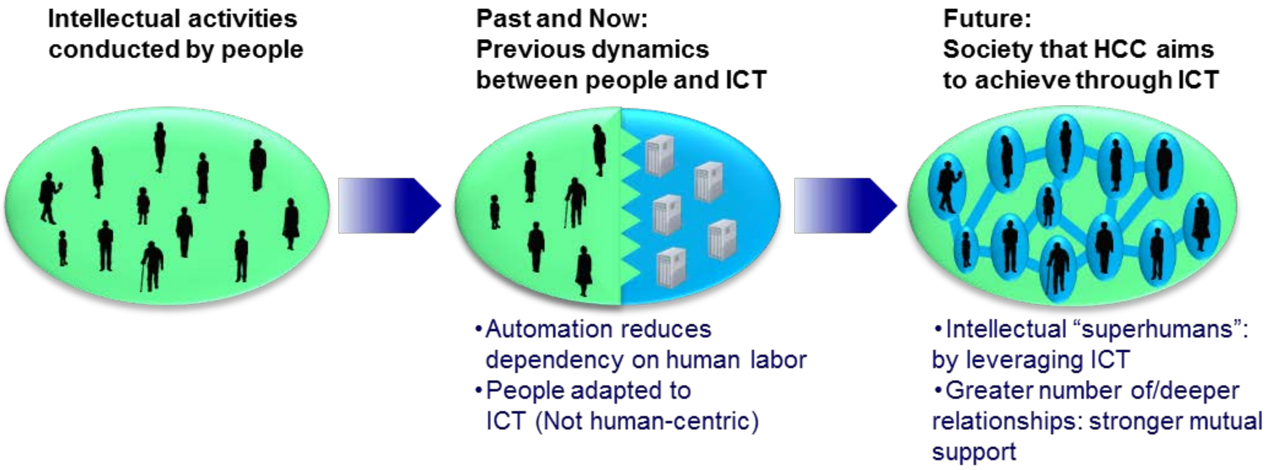

Figure 1: Shift in dynamics between people and ICT

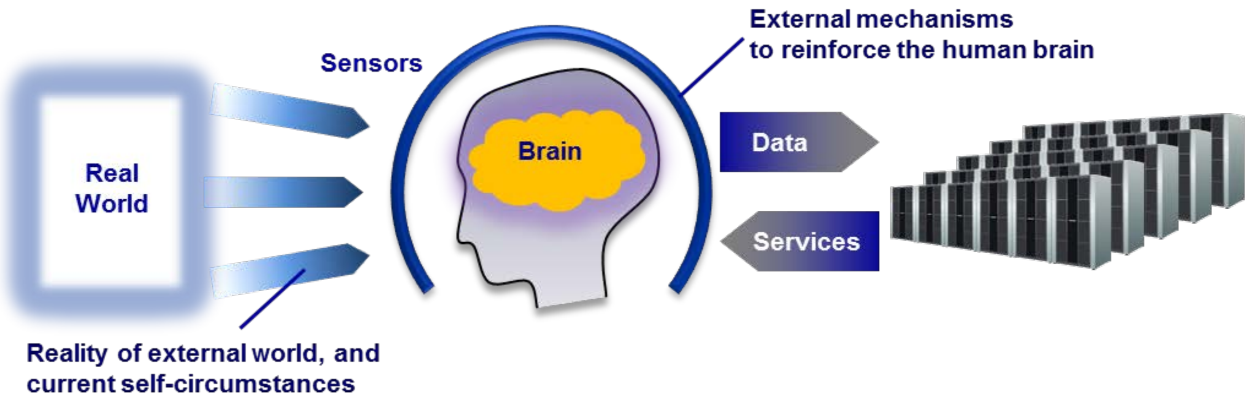

Figure 2: Human-centric computing model for assisting people in intellectual activities

Key underlying concepts for HCC are for ICT to accommodate individuals' needs, and for ICT to support and ensconce people by blanketing their lives with tailored ICT services [1].

In the future, we see an era in which HCC will enable people to have "super-human intellect", by leveraging ICT – in such a society, we will observe a greater number of and deeper social relationships among people and society as a whole, with such social interaction enabling stronger and mutual support and inter-related bonds.

Such collective and inter-social intellects will enable activities and decisions based on, for example, group relationships, communities, and regions, rather than on merely individual knowledge, personal experience, and self-decisions.

We also foresee that such HCC to enhance people's lives and enable activities and decisions based on more sophisticated educated assumptions and collective experience will be available at all times/24 hours a day, supporting people's lives always, whether they are awake or asleep, active or inactive.

2.3 Human-Centric Computing: Futuristic Model

Figure 2 illustrates an example of a futuristic "human-centric computing model" we envision in a "human-centric intelligent society". At the far left is the "real world", and at the far right is the "virtual world".

In this futuristic HCC model, sensors surrounding individuals in the "real world" will capture and recognize the reality of the external world, and current self-circumstances of the individual, while external mechanisms will be leveraged to reinforce the human brain. "Real-world" data shared with the "virtual world" would enable tailored services to be automatically delivered to people, depending on their preferences and both apparent and untapped needs.

We envision that sophisticated and supportive human-centric ICT will enhance people's activities, intellect, and lives through readily-available tailored services based on data derived via sensors from people and a multitude of devices and other objects. Similar to the way corrective vision makes use of eyeglasses and contact lenses to enhance vision, by reinforcing the capabilities of the human brain through external mechanisms leveraging ICT, we envision that HCC will facilitate through external mechanisms the ability of people to enhance their brains, to strengthen their capabilities pertaining to knowledge, memory, senses, various skills including communication, etc.

In this futuristic HCC model, we envision that users will be surrounded by multiple sensors to capture user circumstances and surrounding conditions, and related data will be considered as user context. Furthermore, tailored services available on the cloud, which fit user needs, will be proactively and autonomously offered to users.

Similar to the manner in which people accustomed to corrective vision and become unconscious of wearing eyeglasses or contact lenses, we envision that such tailored services enabled by ICT will unobtrusively and subtly blend into people's lives, to enhance people's intellectual abilities in a variety of situations and opportunities.

In such a human-centric society supported by ICT, users will always have the control and authority to decide which tailored services they wish to select and benefit from.

2.4 Blanketing People's Lives with Services: Healthcare Example

By smartly recognizing user conditions and circumstances, and by offering tailored services that accommodate user needs [3], HCC has the potential to positively impact peoples' lives in a multitude of ways – one such primary example is in the field of "healthcare".

When we consider healthcare services and the dynamics between patients and hospitals and other healthcare facilities, although preventive medicine indeed already exists, currently more common in many countries is a "reactive" approach, in which people usually visit hospitals and seek healthcare after the patients develop symptoms which they feel require medical attention – usually, patients explain their symptoms at hospitals, and based on the doctor's diagnosis, usually recommended or required healthcare is provided.

However, in a world well-supported by HCC and blanketed tailored services, we envision it will be possible to proactively and continuously monitor a potential patient's or a current patient's physical condition, via sensors and data logs across a designated period of time (Fig. 3).

The left half of Fig. 3 shows conventional healthcare approaches, which are not fully supported by HCC, which often require lengthy waits by patients to see physicians, followed often by very brief face-to-face examinations. Instead of taking the time and effort for a cumbersome hospital visit, potential patients may choose to self-medicate instead.

The right half of Fig. 3 illustrates how HCC can be leveraged to proactively offer data-rich patient information to physicians – for example, based on a recent data log. This would enable physicians to more efficiently and accurately make a patient diagnosis.

HCC-based patient-supportive ICT services could autonomously flag an alert when a potential patient displays symptoms which require medical attention, and could continue to monitor the status of the patient after treatment.

2.5 HCC as a Social Catalyst Impacting Social Behavior

We envision that HCC will also contribute significantly toward reinforcing the sustainability of societies. Through unobtrusive and subtle guidance leveraging relevant and timely information, we foresee that ICT will make it possible to offer directional guidance for social behavior of people.

Without sufficient information and lack of real-time data, and without an awareness of how such information is linked between people and relationships, in their social behavior people often make fragmented decisions based quite commonly mostly on assumptions.

However, if abundant and collective real-time data and timely information amassed from a vast number of individuals through HCC could be smartly shared in a data-rich society, such data could function as a "social catalyst" for social behavior, enabling individuals to make self-decisions based on abundant and relevant information (Fig. 4).

Such data as a social catalyst could gently guide individuals in their social behavior, thereby assisting people in making educated, logical and recommended decisions throughout various facets of their daily lives. In a way, such data derived by HCC can have an effect on people that is similar to the effect that so-called conventional social hormones have on human social behavior.

Similar to the way car navigation systems offer real-time directional guidance and support to drivers, in this way, real-time data derived through HCC can act as a gentle and supportive social catalyst for society as a whole.

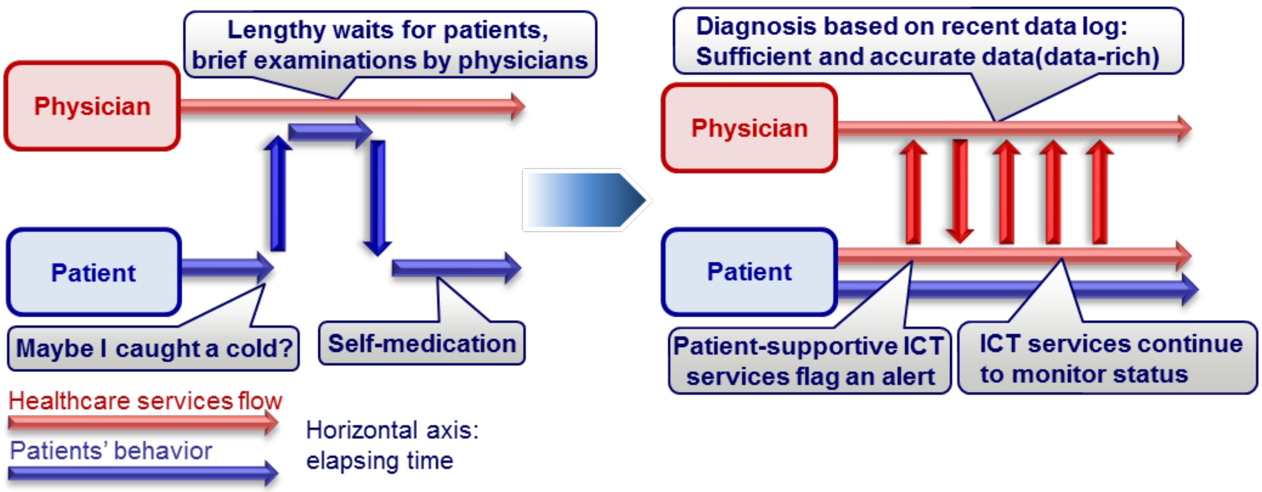

Figure 3: Life "blanketed" with services: healthcare example

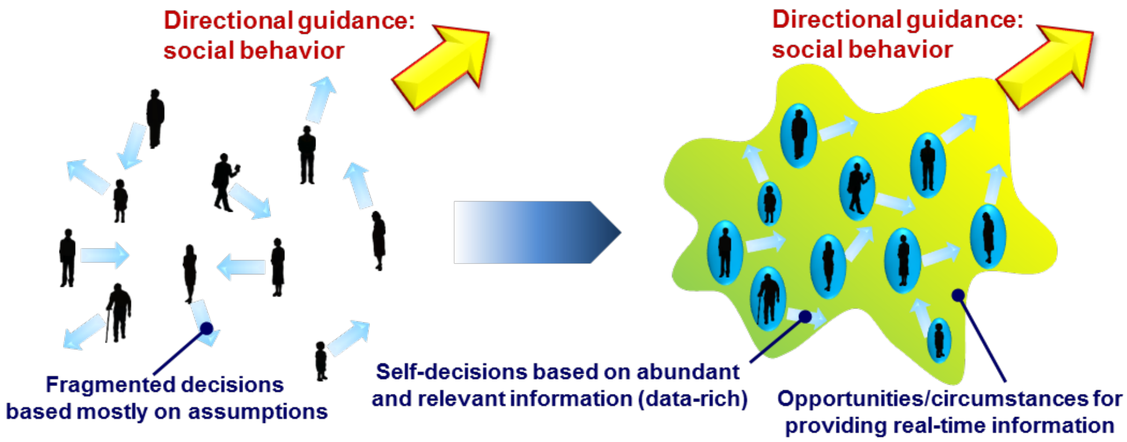

Figure 4: Social catalyst for social behavior

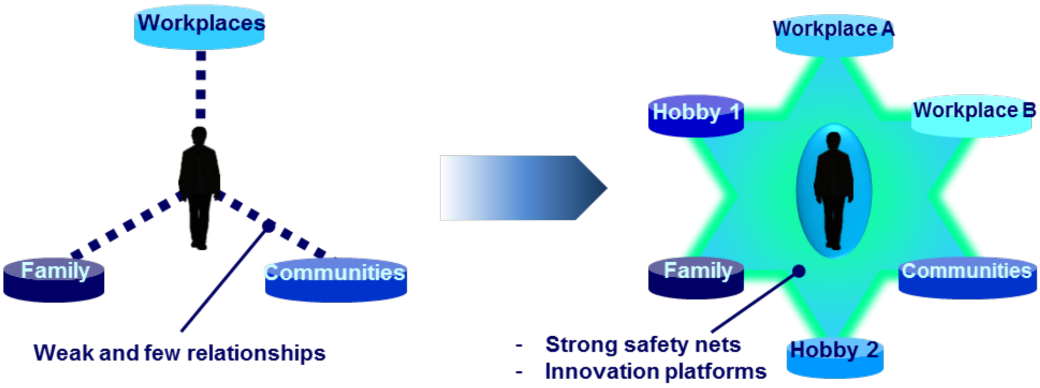

Figure 5: From "trees" to "networks: social communication

2.6 Social Communication: From "Trees" to "Networks"

It can be anticipated that Human-Centric Computing will also have significant impact on social communication, facilitating a shift from "tree-type" social communication to "networked" social communication [4].

Evolution of ICT sees us observing a transition from a conventional "tree-type" social communication approach of the past – in which aspects of an individual's workplace, family, and communities were usually separate and fragmented - to a shift toward "networked" social communication in which there are a multitude of links between facets surrounding an individual's daily life, including multiple workplaces, communities, family, hobbies, etc. (Fig. 5).

In a tree-type social communication approach of the past, societies and enterprises usually focused primarily on efficiencies. In the networked social communication era, more value is placed aspects such as innovation and social happiness.

As witnessed in recent years by the advent of social media, a networked approach to social communication enables strong safety nets and innovative platforms in society.

Such relationships can result in social capital [5] that is accumulated in multiple and lively, active communities.

3 HUMAN-CENTRIC COMPUTING: HIGHLIGHT TECHNOLOGIES

As ICT architecture that supports a human-centric society, we anticipate that such architecture will be "dual-loop", as illustrated in Fig. 6.

The right side of Fig. 6 shows a feedback loop which connects the real world with cyber space, by leveraging HCC. Various data related to people, things, objects, and events is gathered and reflected onto entities in the cyber space. Simultaneously, data will be recognized and understood in real-time, and synthesized as appropriate or ideal output such as tailored services, and fed back to the real world through a variety of methods.

The left side of Fig. 6 illustrates a feedback loop which connects cyber space with a model – massive data accumulated in cyber space is analyzed, and an appropriate model is extracted. Based on simulations results that utilize the model, visualization data is fed back to cyber space and the real world.

Technologies for HCC and for an "intelligent society" are the technologies that will realize these dual feedback loops in a "human-centric intelligent society", with the specific supporting technologies being platform technologies and cloud computing.

Following are highlights of a multitude of HCC technologies that will enable and support a human-centric

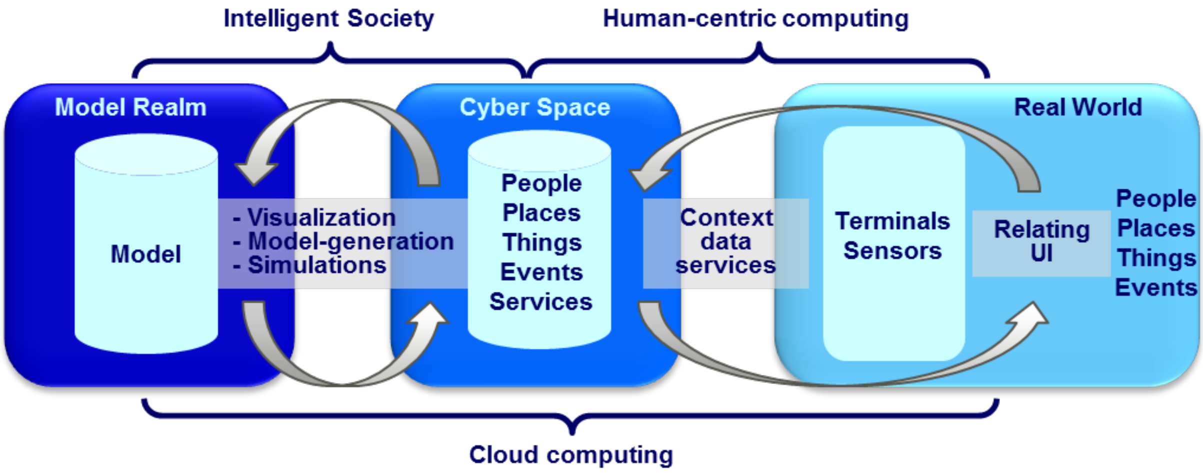

Figure 6: Dual-loop ICT architecture for human-centric computing

intelligent society we envision: the technologies can largely be categorized as being in either the aforementioned "HCC domain" or "intelligent society domain".

3.1 Technologies: Human-Centric Computing Domain

For technologies referenced in the HCC domain of Fig. 6, the objective is to support individuals through ICT so that people can become a step closer toward developing so-called "superhuman intellectuality", to enable safer, secure, and more prosperous lives and societies.

Technologies that support this effort include man-machine interfaces (MMI), robotics, multi-media processing technologies, sensor technologies, and context computing. Such technologies will offer mechanisms to expand input and output that links between computers representing cyber space and the real world.

3.1.1 HCC Technologies: Location-Aware Services

Location-aware services are one example of ICT related to HCC [6].

Figure 7 illustrates cloud computing-based platform technologies to provide location-aware tailored services to smart devices, such as smartphones and tablets. By gathering on the cloud sensor data derived from smart devices, and determining user location, depending on such locations these HCC-relevant technologies can pro-actively provide pre-registered tailored services to users' smart devices [7].

Location-management services developed and illustrated in the same figure use different positioning technologies depending on conditions, and can convert a measured position (a coordinate) into more abstract position information (such as a meeting room or other pre-defined area).

These HCC-relevant technologies enable users to benefit from timely location-aware services, without necessitating user-selection of services, or user-based access to required data.

Developers can use these HCC-relevant technologies to focus on developing higher-level services, enabling users to benefit from location-aware services in a variety of situations. With these technologies, companies can use multiple positioning technologies depending on various circumstances, and can develop services that are independent of any particular positioning technology for location-aware services suited to different situations.

In regards to potential applications of this technology, for example, this technology can be used at medical facilities in which nurses would enter patients' rooms, and the patient's information would automatically appear on the handheld mobile device carried by the nurses. This would increase the efficiency and accuracy of such healthcare.

Another example is in an office environment – this technology can be used to provide a mobile environment that shows all business applications of a user when the user is in the office, could extract business data and customer data when the user is in transit, and can display customer data when the user visits customers.

In the future, there are plans to incorporate this technology into "SPATIOWL", a cloud service that employs positional information. Practical implementation of this technology is anticipated in 2013 [8].

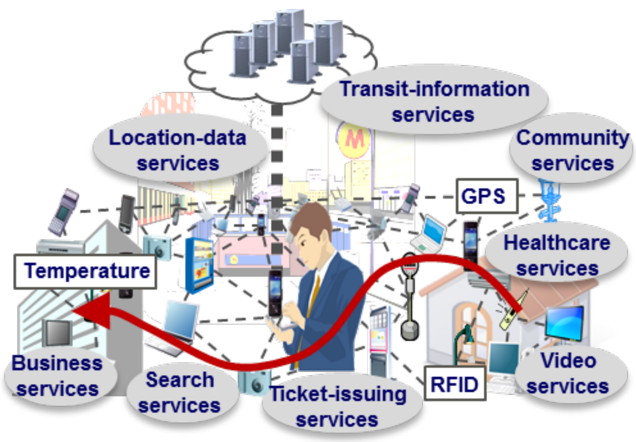

Figure 7: Location-aware services

3.1.2 HCC Technologies: DNA-Based Bio-Sensor Technology

The advent of new infectious diseases, such as SARS and newer viruses similar to SARS, has highlighted the importance of fast detection and preventive measures. There is active research to determine the proteins that cause diseases such as cancer and diabetes, for the objective of early detection and treatment [9].

Figure 8 illustrates a HCC-relevant novel bio-sensor technology that uses DNA to accurately detect proteins 100 times faster than previous methods, and requiring only 1/100 the sample volume, the first technology of its kind in the world [10], [11].

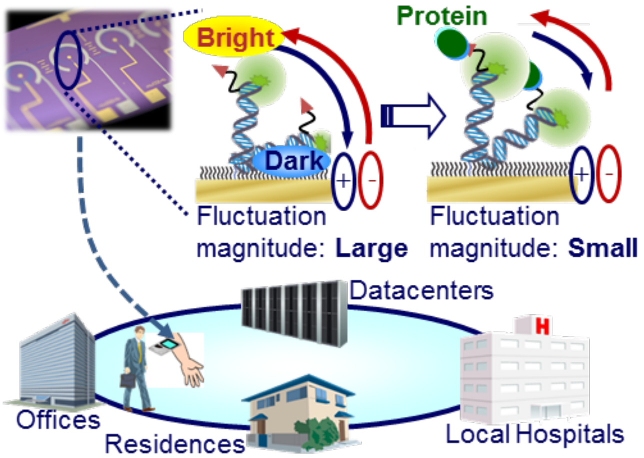

Figure 8: DNA-based bio-sensor technology

The technology employs an electrical field to induce a cyclical motion in negatively charged DNA, and measures the DNA movement as the fluorescentdye applied to the ends of the DNA lights up in the cycle. When the target protein binds to the end of the DNA, the magnitude of the fluctuations between light and dark becomes smaller, enabling detection of protein. This technology enables faster, more accurate detection of proteins as biomarkers of diseases, paving the way for its use in daily health management and maintenance, and early detection and treatment of disease.

Next, to capture target protein, an antibody with high affinity for protein is needed. Conventional antibodies require the employment of a mammalian immune system in order to be developed, thus being costly and not amenable to maintaining a fixed level of quality.

This HCC-relevant technology has been employed to successfully chemically synthesizing artificial antibodies known as DNA aptamers. With high-quality, low-cost DNA aptamers, this technology could be applied to the food industry, where there is a need for reducing the time required to conduct large-scale inspections. For example, in the case of milk, inspections to detect the presence of toxic proteins that are not killed during heat sterilization have been unable to be conducted due to high-cost and significant time required.

3.1.3 HCC Technologies: Socially-Interactive Teddy Bear Robot Prototype

Robotics will also play an important role in the Human-Centric Computing domain, to support people and society.

Figure 9 shows a photo of a "socially-interactive teddy bear robot prototype" that employs various HCC-relevant leading-edge technologies: an extremely unique, user-friendly robot that demonstrates how a MMI can be used to facilitate unobtrusive and user-friendly social interaction.

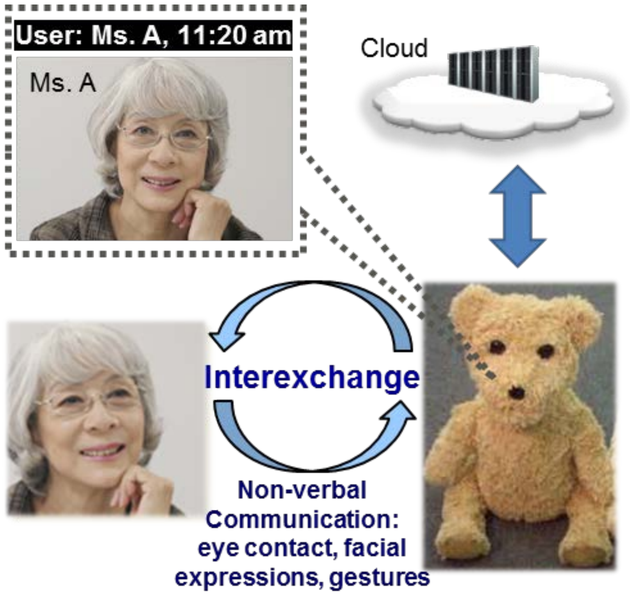

Figure 9: Socially-interactive teddy bear robot prototype

Although it looks very friendly, warm and cuddly, this robot prototype features leading-edge HCC technologies, including: a nose camera, 13 touch sensors, advanced image recognition, and innovative software. The prototype robot can monitor the user's physical condition – such as body temperature, level of alertness, physical activity, and facial expressions such as the degree of a user's smile – such data can be stored on the cloud, and remotely viewed. The prototype robot can also react to touch and sight, with its own movements and sound.

This robot prototype employing HCC technologies can be used in nursing homes or at residences for the elderly to gently remotely monitor senior citizens and interact with them in a warm, friendly manner. It can also be used for educational purposes with young children.

This socially-interactive teddy robot prototype is an interactive companion that can blend into daily life and deliver people-friendly services.

In this way, robotics employing HCC can unobtrusively and gently support individuals in society.

3.2 HCC Technologies: Intelligent Society Domain

When we refer to the "intelligent society" domain of a human-centric intelligent society as outlined in Fig. 6, various innovative and practical HCC-based ICT will be necessary to support such a society.

3.2.1 HCC Technologies: Multimedia Information Retrieval, Classification, and Exploration System: MIRACLES

Figure 10 illustrates a HCC-relevant technology that interactively extracts required data from within massive data on the Internet, by analyzing and visualizing text data and image data. The system is called MIRACLES, which stands for Multimedia Information Retrieval, Classification, and Exploration System.

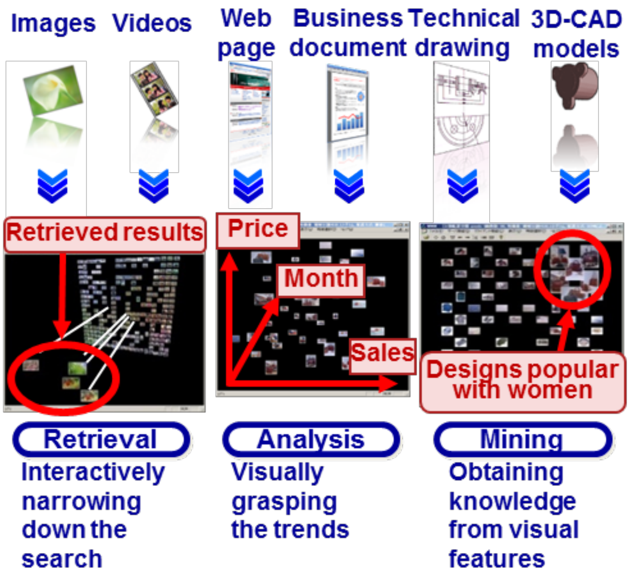

Figure 10: Multimedia Information retrieval, classification, and exploration system (MIRACLES)

The user enters keywords related to the data they seek, and the system retrieves images and text corresponding with those keywords. Next, the system creates categorizes and allocates the data in 3-D, so that similar data is featured near one another. Users can view and walk through the 3-D space, retrieving desired data.

This example shows a marketing application of this system, in which results are extracted for best-selling women's bags. Keywords are searched, then the retrieved data is allocated in 3-D under the categories "price", "month", and "sales".

In this way, this HCC-relevant technology enables interactive retrieval of desired data, such as social preferences and trends, etc.

3.2.2 HCC Technologies: Agricultural Knowledge Management

Cloud computing is already playing an important role in the field of agriculture. An ongoing issue in many countries is how agricultural knowledge and expertise can be passed down to next generations, despite diminishing agricultural human resources in numerous societies – especially among younger generations.

One such example of HCC-relevant cloud computing for agricultural applications is an agricultural cloud as illustrated in Fig. 11 – this technology enables the leveraging of experience and expertise to be passed down to future generations as tacit knowledge [12].

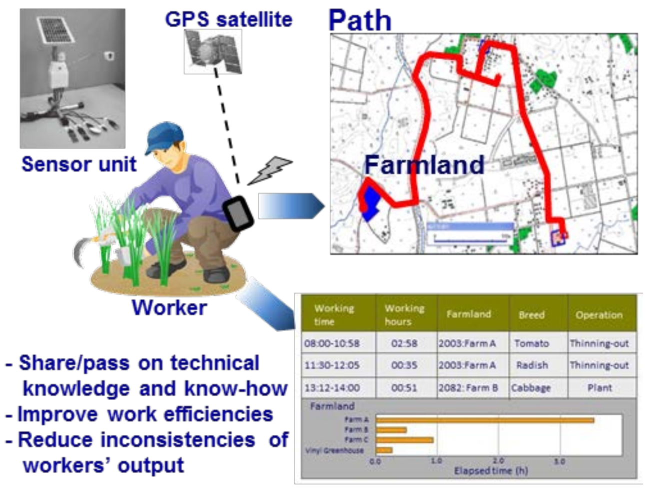

Figure 11: Agricultural knowledge management

This HCC-relevant agricultural cloud known as "Akisai" employs sensors to manage and monitor weather and soil conditions related to crops, to allow fertilizers and agrochemicals to be applied with optimal timing, leading to significant improvements in productivity. Agriculture draws from many years of accumulated experience and expertise.

Traditionally, agricultural products have been produced through a combination of experience and instinct, in other words a farmer's known-how. By using ICT to process this expertise, nearly anyone can access the practical knowledge of farmers, and achieve a leap in productivity.

By leveraging this innovative agricultural cloud technology, younger generations can play a far more active role in enterprise, enabling such valuable knowledge to be put to broader and more effective use.

In this way, there is growing potential for the application of HCC-relevant ICT in agricultural management.

3.3 HCC Technologies: Cloud Computing Technologies

In order to achieve a human-centric intelligent society through HCC, we envision that cloud computing [13], [14] will play an integral role (Fig. 6).

3.3.1 HCC Technologies: Next-Generation Server Enabling Both High-Performance and Flexibility

With the spread of cloud computing, the role expected of datacenters delivering cloud services is significantly evolving.

For example, big data, transmitted by large volumes of sensors in such as fields as life-logging, medicine, and agriculture, is collected in datacenters and put to use. For these applications and increasing diversity of services, datacenters are expected to deliver efficient and flexible processing.

Figure 12 illustrates a next-generation server that employs resource pool architecture to enable the delivery of high-performance server and storage capabilities as needed [15], [16].

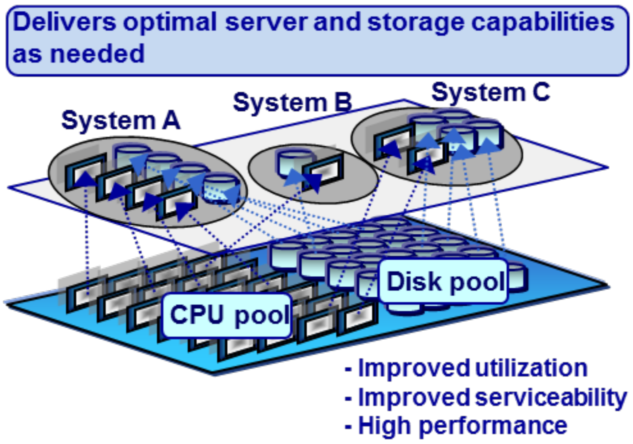

Figure 12: Next-generation server employing resource pool architecture

In accordance with user requirements for CPUs, HDDs, and other needs, necessary resources can be allocated from the pool, enabling servers to be configured on demand.

Using server resources from the pool, storage capabilities are delivered by configuring the middleware, which controls HDD management and data management functions.

The disk pool is connected to the CPU pool via a high-speed interconnect disk area network, enabling the delivery of the same disk access capabilities as the local disks in a typical server.

Providing flexible and high performance IT infrastructure based on cloud computing and HCC-relevant technologies will contribute to processing big data and the realization of ICT services.

3.3.2 HCC Technologies: Power-Saving System Control Technology For Container Datacenters

With the spread of cloud computing, the market scale for datacenters is growing, as is the amount of energy consumed by these datacenters.

In order to respond to the increasing need for datacenters, in addition to conventional large-scale data centers, the industry has seen progress in the commercialization of container datacenters, which require low up-front investment and can be quickly constructed.

Figure 13 outlines a power-saving system control technology for container datacenters that reduces total energy consumption by up to 40% when compared to conventional technology [17].

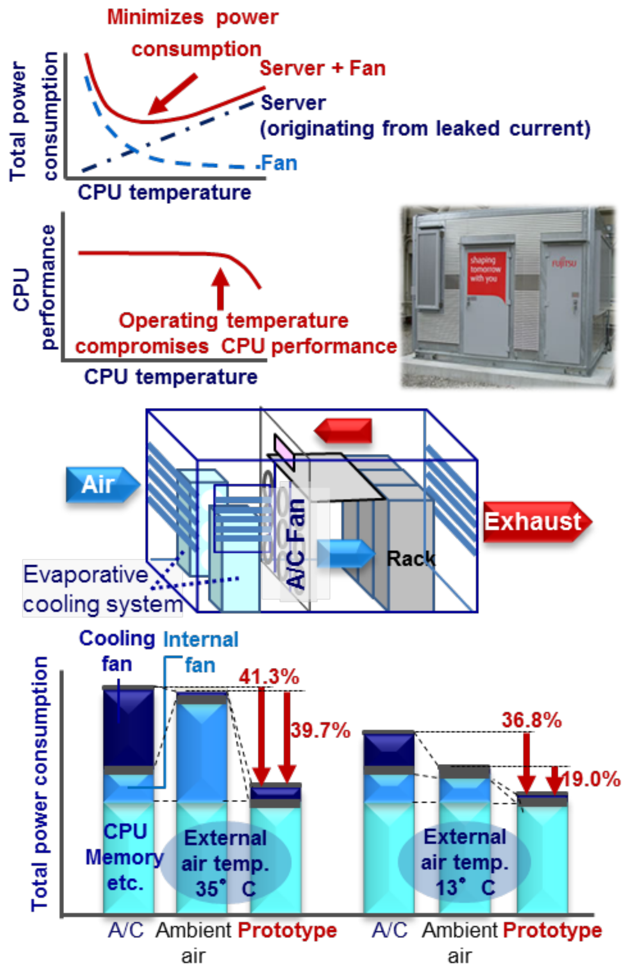

Figure 13: Power-saving system control technology for container datacenters

Total power consumption in servers is comprised of consumption from CPU and memory, combined with that of the server's own internal fans and the cooling fans in the room - by removing the internal fan, that portion of the power requirement was reduced.

By leveraging information regarding CPU temperature and server power consumption information, this technology enables simultaneous control all of the container cooling fans in order to minimize overall energy consumption.

Furthermore, based on CPU temperature and location information, the technology controls local container A/C fans to ensure that the system never reaches an operating temperature where CPU performance is comprised.

These two air-conditioned controls for servers without internal fans conserve power consumed by datacenters, helping to facilitate the spread of cloud computing that employs HCC-relevant technologies.

3.3.3 HCC Technologies: Energy Harvesting Technology

As observed in numerous countries worldwide, as societies experience transitions in energy sources and explore new types of energy, new developments in energy harvesting are underway [18].

Energy harvesting involves the harvesting and conversion of energy – such as light or heat, for example – from one's surroundings into energy. Figure 14 illustrates a hybrid energy harvesting device, which can generate electricity from heat and light available in the environment, and can be used in combination with cloud services. The hybrid power generator features dual-mode operation that can handle both photo-voltaic and thermo-electric modes [19], [20].

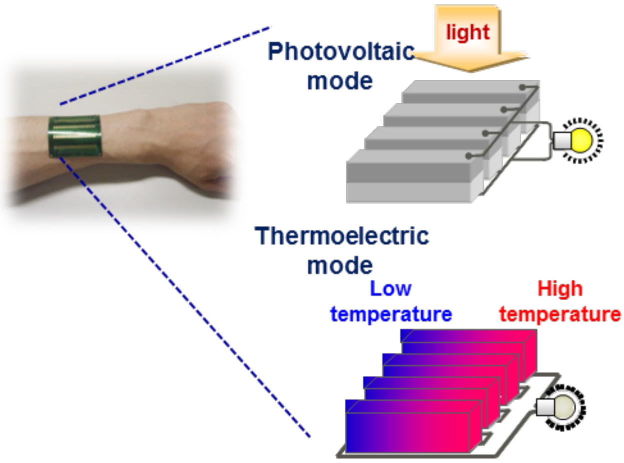

Figure 14: Hybrid energy harvesting device

With this technology, with a single device, it is possible to derive ambient energy from two separate sources – such as heat or light – which previously could only be handled by combining individual devices.

Furthermore, because the cost of this hybrid device is economical, this technology paves the way to widespread use of energy harvesting devices which generate self-sufficient power from the surrounding environment.

Since there is no need for electrical wiring or battery replacements, this energy harvesting technology could enable the use of sensors in previously unserved or underserved applications and regions – when used with sensors and cloud services, the technology has great potential for powering a variety of sensor networks and medical-sensing technologies.

4 CONCLUSION

Accelerated globalization has led to an alarming rise in increasingly intertwined, complex and daunting global-scale societal issues that significantly and directly impact people's lives in both industrialized and developing countries worldwide.

Simultaneously, the continuous widespread expansion of practical-use leading-edge ICT along with continuous and explosive growth of massive data in society – in particular the advent and leveraging of cloud computing and big data – have given emergence to opportunities and needs for ICT to provide "human-centric solutions" to handle such globally intertwined, complex and daunting societal issues.

We outlined how we envision how Human-Centric Computing (HCC) technologies as vital frameworks will drive the shift toward, and provide much of the essential and practical means for enabling and supporting a resilient, prosperous, and sustainable "human-centric intelligent society" we envision for the future.

We foresee that leveraging leading-edge HCC technologies - such as those which we highlighted in this paper - will play an essential role in enabling and supporting a resilient, prosperous, and sustainable human-centric intelligent society we envision for the future.

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