Abstract The rapid development of the Internet and Internet of things accelerates the emergence of the hyper world. It has become a pressing issue to realize the organic amalgamation and harmonious symbiosis among human, computers and things in the hyper world, which consists of the social world, physical world and information world (cyber world). In this paper, the no-
nation of Wisdom Web of Things (W2T) is proposed to address this issue. As inspired by the physical cycle of the physical world, the W2T focuses on realizing the harmonious symbiosis of human-computers-things by a “Things-Data-Information-Knowledge-Wisdom-Services-Human-Things” cycle. A W2T data cycle system is designed to implement such a cycle. This is a practically technological way to realize the harmonious symbiosis of human-computers-things in the emerging hyper world.

Keywords Wisdom Web of Things · Internet of things · Data cycle · Active service · Transparent service

1 Introduction

The Internet connects dispersive computers into a global computer network. On this network, the World Wide Web (Web) provides a global platform for information storage, resource sharing, service publishing, etc. An information world, called cyber world, comes into being between the human world (social world) and the thing world (physical world).

In recent years, advanced information technologies accelerate the development of cyber world [35,36]. On one hand, various new Internet/Web based technologies, such as semantic Web [3,10,11], grid computing, services computing, and cloud computing [2,14], make the cyber world become not only a research/service platform but also a global communication and cooperation space in which various virtual communities, associations and organizations have been established. The cyber world is constantly expanding towards the social world. On the other hand, embedded technologies, RF automated recognition (RFID) technologies, wireless data communication technologies and ubi-comp technologies impel the forming of the Internet of things (IoT) [5,58]. A large number of sensor nets, embedded appliance nets and actuator nets (SEA-nets) have been constructed. The transparent computing technologies [51,67–70,82] ensure the effective deployment and publishing of resources/services on these heterogeneous nets. Furthermore, these SEA-nets are integrated and connected into the Internet by various gateways. The Web of things (WoT) [9,48] is emerging on the IoT to integrate the sensor data coming from various SEA-nets into the Web. The cyber world is also extending towards the physical world (thing world).

At present, various Internet/Web and IoT based applications, such as Web 2.0 [44,45], Web 3.0 [17,27], smart world [36,42], smart planet [21], green/eco computing [26,60], etc., accelerate the amalgamation among the cyber, social and physical worlds. It can be predicted that the cyber world composed of computers will be gradually syncretized with the social world composed of human and the physical world composed of things in the upcoming future. A hyper world [25,34] will come into being on the IoT. It consists of the cyber world, social world and physical world, and uses data as a bridge to connect all of human, computers and things. Such a data based hyper world will bring a profound influence in both work and life to the whole human society and
every member in it. Multi-domain experts should closely cooperate to cope with the subsequent challenges and opportunities.

The core challenge brought by the hyper world is to realize the organic amalgamation and harmonious symbiosis among human, computers and things using the Internet/Web based technologies, ubicomp technologies and intelligence technologies, i.e., to make every thing in the hyper world more “Intelligent” or “Smart” by computers or cells with storage and computing capabilities, to provide active, transparent, safe and reliable services for individuals or communities in the hyper world. Though various theories and technologies have been developed to realize different levels of intelligent services on the Internet/Web and various SEA-nets, they are not fit to the hyper world which is built on top of the IoT.

This paper proposes the notion of Wisdom Web of Things (W2T) which represents a holistic intelligence methodology for realizing the harmonious symbiosis of human-computers-things in the hyper world. A W2T data cycle system is also designed to implement a “Things-Data-Information-Knowledge-Wisdom-Services-Human-Things” cycle. The W2T provides a practical technological way to realize the harmonious symbiosis of human-computers-things in the emerging hyper world. The remainder of this paper is organized as follows. Section 2 discusses intelligence in the hyper world. Section 3 proposes the W2T as a holistic intelligence methodology in the hyper world. For realizing the W2T, Section 4 describes a W2T data cycle system. Three use cases are introduced in Section 5. Finally, Section 6 gives concluding remarks.

2 Intelligence in the hyper world

2.1 Web Intelligence (WI) and Brain Informatics (BI)

The Web significantly affects both academic research and daily life, revolutionizing the gathering, storage, processing, presentation, sharing, and utilization of data/information/knowledge. It offers great opportunities and challenges in many areas, including business, commerce, marketing, finance, publishing, education, and research and development.

Web Intelligence (WI) [71,63,31,32,74,78,80] may be viewed as an enhancement or an extension of Artificial Intelligence (AI) and Information Technology (IT) on a totally new domain - the Web. It focuses on the research and development of new generations of Web-based information processing technologies and advanced applications to push technologies towards manipulating the meaning of data and creating distributed intelligence.

The goals of WI can be refined as the development of Wisdom Web [72, 73], which is involved with the following top 10 problems [31,32];

- Goal-directed Services (best means/ends),
- Personalization (identity),
- Social & psychological context (sensitivity),
- PSML, i.e., Problem Solver Markup Language (representation),
- Coordination (global behavior),
- Meta-knowledge (planning control),
- Semantics (relationships),
- Association (roles),
- Reproduction (population),
- Self-aggregation (feedback).

Though many efforts [13,19,28,49] have been made to solve the above problems, it is difficult to develop such a Wisdom Web only using the existing AI and IT technologies.

Brain Informatics (BI) [76,77,79] is an emerging interdisciplinary field to study human information processing mechanism systematically from both macro and micro points of view by cooperatively using experimental, theoretical, cognitive neuroscience and WI centric advanced information technology. It emphasizes on a systematic approach for understanding human intelligence in depth. On the one hand, WI based portal techniques (e.g., the wisdom Web, data mining, multi-agent, and data/knowledge grids) will provide a new powerful platform [75] for the BI; On the other hand, new understandings and discoveries of human intelligence in the BI, as well as other domains of brain sciences (e.g., cognitive science and neuroscience) will yield new WI researches and developments. At present, some new human-inspired intelligent techniques and strategies [65,66] have been developed to offset the disadvantages of existing intelligence technologies, especially logic-based technologies.

2.2 Ubiquitous Intelligence (UI) and Cyber-Individual (CI)

The development of RFID technologies and wireless data communication technologies impels the forming of IoT. The real physical things are called u-things if they are attached, embedded or blended with computers, networks, and/or some other devices such as sensors, actors, e-tags and so on [35]. The IoT makes it possible to connect u-things dispersed in various SEA-nets and ubi-comp applications for realizing a Ubiquitous Intelligence.

Ubiquitous Intelligence (UI) [36,55], generally speaking, is that intelligent things are everywhere. It means pervasions of the smart u-things in the real world, which would evolve towards the smart world filled with all kinds of smart u-things [35–37]. The construction of smart u-things is a core issue in the UI. So-called smart u-things are the active/reactive/proactive u-things, which are with different levels of intelligence from low to high. An ideal smart u-thing should be able to act adaptively and automatically. Its construction is involved with the following 7 challenges [35,37,38]:

- Surrounding situations,
- Users’ needs,
- Things’ relations,
- Common knowledge,
- Self awareness,
– Looped decisions,
– Ubiquitous safety (UbiSafe).

Constructing such a smart u-thing is involved with various challenging topics, including the gathering and mining of logs [39], context modeling [18, 23, 24, 54], user modeling [4, 15, 16, 52], etc. However, challenges brought from the real world complexity are difficult to be solved. For realizing the UI, the human essence in the cyber world needs to be re-examined and analyzed. The research of Cyber-Individual (Cyber-I or CI) [59] represents such a re-examination and analysis. A Cyber-I is a real individual’s counterpart existing on the cyberspace. It is a kind of unique and full descriptions to human being in the digital world. On the one hand, ubicomp technologies make it possible to collect individual’s information every time and everywhere. With the increasing power of computers, networks, ubiquitous sensors and massive storages, it is no longer a dream that everyone on this planet can have a Cyber-I going with and even beyond his/her whole life. On the other hand, a comprehensive and exact Cyber-I can effectively guide smart u-things to provide active and transparent services for realizing the UI.

2.3 A holistic intelligence in the hyper world

For realizing the harmonious symbiosis of human-computers-things, u-things in the hyper world need to be intelligentized for providing active, transparent, safe and reliable services. This intelligentizing will realize not only individual intelligences but also a holistic intelligence, i.e., all of related u-things can intelligently cooperate with each other for each application. Realizing such a holistic intelligence will bring new challenges and opportunities for intelligence researches:

– The hyper world is involved with heterogeneous networks, service types, data forms and contents, efficiency/accuracy requirements, etc. Thus, it is impossible to realize a holistic intelligence in such a complex environment only separately using the above WI, BI, UI and CI. For the WI supported by the BI, though the ubicomp oriented data/services have been mentioned at the beginning, related researches and developments mainly focused on Web based data/services because of lacking the IoT and WoT, which can provide an effective approach to dynamically and largely gather the real-time sensor data coming from different SEA-nets, and realize active and transparent services every time and everywhere. For the UI supported by the CI, though recent studies begin to focus on mining a large number of historical data for providing higher quality of services, related researches and developments were mainly oriented to specific applications and data because of lacking effective technologies and strategies to organize, manage, mining and utilize the multi-aspect real-time data and historical data, as well as information and knowledge derived from the data. Thus, the holistic intelligence research in the hyper world will bring new challenges to the WI, BI, UI and CI.
The infrastructure of hyper world consists of the Internet and a number of SEA-nets. It is possible to continuously and dynamically gather both real-time sensor data and historical Web data in the hyper world by the IoT and the WoT. Moreover, grid computing, cloud computing and transparent computing also make it possible to integrate the powerful storage and computing capabilities on the IoT for effectively storing, managing, mining and utilizing the gathered data, as well as the information and knowledge derived from data. Based on such an infrastructure, the hyper world will provide significant opportunities to the holistic intelligence research, which will integrate the WI, BI, UI and CI to develop a new holistic intelligence methodology for realizing the harmonious symbiosis of human-computers-things in the hyper world.

In summary, the hyper world makes it possible and necessary to integrate the separate intelligence researches into a holistic research. As shown in Fig. 1, in this holistic research the WI, BI, UI and CI are independent and promoted each other. Finally, a holistic intelligence methodology with its associated mechanisms can be developed to realize the harmonious symbiosis of human-computers-things in the hyper world.

3 Wisdom Web of Things

The Wisdom Web of Things (W2T) is a “Wisdom” WoT. It is an extension of Wisdom Web in the IoT age. The “Wisdom” means that each of things in the WoT can be aware of both itself and others to provide the right service for the right object at a right time and context. Thus, the W2T is not a copy of Web
Table 1  A comparison between the Web and W2T

<table>
<thead>
<tr>
<th></th>
<th>Web</th>
<th>W2T</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infrastructure</td>
<td>Internet</td>
<td>Internet of things</td>
</tr>
<tr>
<td>Function</td>
<td>a sharing platform and communication space</td>
<td>an environment to provide active, transparent, safe and reliable services for the harmonious symbiosis of human-computers-things in the hyper world</td>
</tr>
<tr>
<td>Storing and Computing</td>
<td>different types of computers</td>
<td>all electronic media with the capabilities of storage and computing (including different types of computers, PDAs, mobile telephones, embedded chips, and so on.)</td>
</tr>
<tr>
<td>Medium</td>
<td>reliable data sources and relatively stable data streams</td>
<td>various data availabilities, data stream modes, and data gathering strategies</td>
</tr>
<tr>
<td>Data Characteristic</td>
<td>data and user preference modeling</td>
<td>not only data and user preference modeling but also space modeling (including environment modeling, thing modeling, context modeling, user behavior modeling, etc.)</td>
</tr>
<tr>
<td>Modeling</td>
<td>domain knowledge for the data and computing integration</td>
<td>both domain knowledge and common sense knowledge for guiding the Web and ubicomp</td>
</tr>
<tr>
<td>Formal Knowledge</td>
<td>a human centric mode (i.e., users choose the appropriate services based on individuals' judgments about the current Web environments.)</td>
<td>a ubiquitous awareness mode (i.e., all of human, computers and things can be aware of themselves and others dynamically for providing active and transparent services.)</td>
</tr>
<tr>
<td>Awareness Mode</td>
<td>computing on the Internet/Web</td>
<td>computing in everywhere</td>
</tr>
<tr>
<td>Computing Mode</td>
<td>passive services</td>
<td>both active services and passive services</td>
</tr>
<tr>
<td>Service Mode</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

on the IoT. As shown in Table ??, it is different from the existing Web in many aspects, including infrastructure, function, data characteristic, modeling, and so on. Obviously, such a W2T is impossible constructed only using the existing intelligence technologies which are oriented to specific human, computers, things.

The nature is based on materials. An effective material cycle ensures the harmonious symbiosis of heterogeneous things in the nature. Similarly, the hyper world is based on data. Thus, constructing the W2T for the harmonious symbiosis of human-computers-things in the hyper world requires a highly effective “Things-Data-Information-Knowledge-Wisdom-Services-Human-Things” data cycle:

- Things-Data: Various data of things are collected into a distributed integrated data center through the WoT. These data include the real-time data
of things coming from the sensors in SEA-nets and measuring equipments (such as MRI, EEG, CT), the Web accessible historic data of things stored on the Web, and the data of Web produced on the Web.

- Data-Information: After data cleaning, integration and storage, both sensor data and Web data are analyzed and re-organized to generate multi-aspect and multi-granularity data information by various data mining/organization methods. The obtained data information is also described and stored in the data center.

- Information-Knowledge: The valuable knowledge is extracted from the data information by various modeling. Other related knowledge is also gathered and described using knowledge engineering technologies. All of knowledge is stored in the data center.

- Knowledge-Wisdom: Based on the obtained knowledge, the top 10 problems of Wisdom Web and 7 characteristics of smart u-thing are studied to develop the key intelligence technologies and strategies.

- Wisdom-Services: An active and transparent service platform is constructed on the integrated data center using the developed intelligence technologies and strategies. It can provide active, transparent, safe and reliable services by synthetically utilizing the data, information and knowledge in the data center.

- Services-Human: The service platform provides various active and transparent services to individuals and communities by a variety of sensors and actuators.

- Human-Things: During the process of receiving services, human continues to influence the things around him/her and brings the changes of things. Finally, the data reflecting these changes are collected into the integrated data center.

As shown in Fig. 2, a variety of sensors, storage and computing terminals in the IoT provide a data storage and conversion carrier for implementing the above data cycle. The emerging WoT provides a transmission channel of data cycle. Therefore, the core problem of data cycle construction is to develop a highly efficient data cycle system.

4 A W2T data cycle system

4.1 The system framework

Figure 3 illustrates the system framework of W2T data cycle system. It includes two parts, W2T data conversion mechanism and W2T data/service interface. The W2T data conversion mechanism is the main body of cycle system and used to drive the process of data cycle, as shown in the right of Fig. 3. The W2T data/service interface includes two middlewares and is used to connect the cycle system to the WoT, as shown in the center of Fig. 3.
Fig. 2 A data cycle in the hyper world

Fig. 3 A W2T data cycle system
4.2 The W2T data conversion mechanism

The W2T data conversion mechanism includes a group of information technologies to transform data forms along the “Things-Data-Information-Knowledge-Wisdom-Services-Human-Things” process. As shown in the center of Fig. 4, it includes the following five levels:

- The data level of technologies is involved with various data management and pre-processing technologies, including data collection, cleaning, integration, storage, etc., for completing the “Things-Data” sub-process of the above data cycle. Because the objective data include sensor data, Web accessible data and Web data, the data collection is a core issue at this level. It is involved with not only collecting data from the Web and information systems, but also producing data by deploying sensors and embedded chips [20,50] or designing and implementing cognitive experiments [30,81].
The data integration is also an important issue because of the differences on data formats, contents and applications.

- The *information* level of technologies is involved with information extraction, information storage and information organization for completing the “Data-Information” sub-process of data cycle. Because of the limited data transmission and computing capabilities, it is necessary to perform the off-line information extraction and organization before services are requested. This is especially important to the hyper world which includes mutable data, computing and network environments. However, the existing technologies cannot meet the requirements of off-line information extraction and organization. Thus, it is necessary to study human information processing and organization mechanisms, such as induction [30], for developing the new information level of technologies, such as granularity division, basic level setting, and starting point setting [65,66].

- The *knowledge* level of technologies is involved with knowledge extraction and knowledge expression for completing the “Information-Knowledge” sub-process of data cycle. The core issues include model, common sense and knowledge retrieval. The studies of human knowledge expression and storage are also implemented to develop the more effective technologies of knowledge expression and storage.

- The *wisdom* level of technologies mainly focuses on the above top 10 problems of Wisdom Web and 7 characteristics of smart u-thing for completing the “Knowledge-Wisdom” sub-process of data cycle. The autonomy oriented computing [33], granular computing [62,64], and complex network [53] are three core theories for realizing “Wisdom” on the WoT which includes enormous data and heterogeneous networks. The results of human intelligence studies are also used to develop new intelligence technologies and strategies.

- The *service* level of technologies is involved with service construction, service publishing and service integration on the Internet/Web and various SEA-nets for completing the “Service-Human” sub-process of data cycle. They are based on grid computing, cloud computing and transparent computing, and oriented to various specific applications in the hyper world, such as pervasive elderly/kid care, active and transparent service platform for depression, etc.

The above technologies are realized as an integrated data center and an active and transparent service platform, as shown in the right of Fig. 4.

As shown in the left of Fig. 4, the five levels of technologies are integrated by a domain driven data conceptual modeling. Such a data conceptual modeling is not the traditional conceptual schema design of databases/metadata or the ontological modeling of data related domain knowledge. It models the whole process of data cycle by different dimensions and has various specifications on the different levels of conversion mechanism:

- At the data level, it can be specified as the conceptual schema designs of databases and data warehouses.
<table>
<thead>
<tr>
<th>Environment</th>
<th>Web Application Servers</th>
<th>Hypw-DKServer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>the Web on the Internet</td>
<td>the WoT on the IoT</td>
</tr>
<tr>
<td>Operating System</td>
<td>operating systems in computers (such as Windows, Unix, Linux, etc.)</td>
<td>new-style network operating systems on various networks</td>
</tr>
<tr>
<td>Main Function</td>
<td>supporting the establish-</td>
<td>supporting the establishment, deployment and management of data/model/knowledge services</td>
</tr>
<tr>
<td></td>
<td>ment, deployment and man-</td>
<td></td>
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<tr>
<td></td>
<td>agement of static and dy-</td>
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<tr>
<td></td>
<td>namic Web applications</td>
<td></td>
</tr>
<tr>
<td>Protocol</td>
<td>standard Web protocols (such as HTTP, FTP, SOAP, WSDL, UDDI and so on.)</td>
<td>new-style standardized protocols for data/model/knowledge communications, descriptions and publishing</td>
</tr>
<tr>
<td>External Interface</td>
<td>database interfaces for main database systems such as Oracle, SQL Server, DB2, and so on.</td>
<td>database interfaces for main database systems, and knowledge/model base interfaces for the existing/developed description languages of knowledge/models</td>
</tr>
</tbody>
</table>

- At the information level, it can be specified as the conceptual descriptions of metadata, cases and data characteristics.
- At the knowledge level, it can be specified as space/user/thing conceptual modeling, domain/common-sense knowledge modeling, and knowledge structure modeling.
- At the wisdom level, it can be specified as agent modeling, granular structure modeling, network and network behavior modeling, as well as the modeling of human higher information processing courses.
- At the service level, it can be specified as the applications of the above different levels of conceptual models.

4.3 The W2T data and service interface

The W2T data and service interface includes two middlewares, hyper world data/knowledge application server (Hypw-DKServer) and hyper world transparent service bus (Hypw-TSBus). They are used to connect the data cycle system to the WoT for making it “Wisdom”.

The Hypw-DKServer is a software middleware for the service publishing on the WoT. It can support centralized or distributed data/model/knowledge publishing and respond to data/model/knowledge requests coming from the Internet and various SEA-nets. Different from the existing Web based application servers, such as Weblogic, Tomcat, Jboss, etc., the Hypw-DKServer is an entirely new WoT based application server, as shown in Table 2.

The Hypw-TSBus is a software middleware for the service integration on the WoT. It can support dynamic service discovery, service evolution, service
Table 3 A comparison between ESB platforms and the Hypw-TSBus

<table>
<thead>
<tr>
<th></th>
<th>ESB platforms</th>
<th>Hypw-TSBus</th>
</tr>
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<tbody>
<tr>
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<td>the Web on the Internet</td>
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<tr>
<td>Operating System</td>
<td>operating systems in computers</td>
<td>new-style network operating systems on various networks</td>
</tr>
<tr>
<td>Main Function</td>
<td>providing a Web oriented infrastructure for the process-description driven service discovery and integration</td>
<td>providing a WoT oriented infrastructure for the purpose-driven dynamic service discovery, evolution and integration</td>
</tr>
<tr>
<td>Other function</td>
<td>supporting message routing, message conversion, message expansion, protocol intermediary, security validation, event handling, service scheduling, etc.</td>
<td>supporting message routing, message expansion, security validation, event handling, etc.</td>
</tr>
</tbody>
</table>

composition, and security validation for meeting various service requests on the Internet/Web and SEA-nets. Different from the existing Enterprise Service Bus (ESB), such as WebSphere ESB (WESB), BizTalk Server, etc., the Hypw-TSBus is an entirely new WoT based service bus, as shown in Table 3.

5 Case studies of applications

In this section, we address 3 use cases to demonstrate the usefulness of the proposed W2T methodology.

5.1 The W2T based brain data center

Different from traditional human brain studies, Brain Informatics (BI) emphasizes on a systematic approach for the human thinking centric investigation, which is complex and involved with multiple inter-related functions with respect to activated brain areas and their neurobiological processes of spatio-temporal features for a given task. A series of cognitive experiments are designed based on a systematic methodology of experimental design to obtain multiple forms of human brain data, which are involved with multiple granularities and aspects of human thinking centric cognitive functions. A systematic analysis methodology is also proposed to comparatively/synthetically analyze these data. For supporting such a systematic BI study, a brain data center needs to be developed to realize not only the data storage and publishing oriented data management but also the systematic analysis oriented management. This section presents the W2T based brain data center which is a global BI research platform for supporting the whole process of BI study. Guiding by this brain data center, various BI experimental studies and BI data analysis studies can be integrated to realize a holistic systematic BI study.
The issue of brain database construction is a long-time focus in brain science. Various brain databases [1, 12, 41, 43] have been constructed to effectively store and share heterogeneous brain data, especially EEG (electroencephalogram) data and fMRI (functional magnetic resonance imaging) data focused by present BI study. However, these brain databases mainly focus on data storage and publishing. They cannot effectively support the systematic BI study. Based on all of the above fundamental considerations, we will develop a W2T based brain data center, as shown in Fig. 5, which can be described as follows.

BI is a data-centric scientific study whose process can be generalized as a BI data cycle, including data production, data collection, data storage, data management, data description, data mining, information organization, knowledge extraction, knowledge integration, and knowledge utilization. All of BI research activities apply themselves to impel this data cycle. Thus, to support the systematic BI study, the first step is to collect heterogeneous brain data, including not only experiment data obtained by BI experimental studies but also derived data, information and knowledge obtained by BI data analysis studies. These data/information/knowledge are transferred via the Internet/WWW and SEA-nets to distributed brain databases as shown in Fig. 5.

A new conceptual data model, named Data-Brain [6, 7], is used to integrate the data/information/knowledge stored in brain databases. The Data-Brain models the four aspects of systematic BI methodology by four dimensions. Related domain ontologies are also integrated into these dimensions. Based on the Data-Brain, the information and knowledge derived from data are integrated and organized as Data-Brain based BI provenances and sub-dimensions of Data-Brain, respectively. They provide multi-granularity and multi-aspect semantic descriptions of brain data for data understanding and utilization. The Data-Brain, BI provenances and brain data form a multi-level brain data/knowledge base which provides data/information/knowledge services for BI researchers and other research assistant systems, such as the Global Learning Scheme for BI (GLS-BI). The GLS-BI is a brain data analysis platform which models BI experimental and data analysis studies, as well as available BI data and computing resources, as various data agents and analysis agents to support multi-aspect brain data analysis by various assistant functions, including dynamical mining process planning, workflows filter and performance, etc. Finally, all of the functions provided by the brain data/knowledge base and the GLS-BI are enclosed as services on the BI portal and published by the Hypw-TSBus and the Hypw-KDServer to provide transparent and active research supporting services during the whole BI research process.

As a BI data cycle system, the W2T based brain data center guides a complete data cycle in the global BI research community, from acquisition of heterogeneous data/information/knowledge in the physical world to the provision of active services in the cyber world to BI researchers in the social world. By this brain data center, BI researchers (in the social world), brain detecting equipments (in the physical world), and data/computing resources
(in the cyber world) are harmonious and symbiosis to impel the BI study together.

5.2 The W2T based kid care platform

An interesting survey [47] recently made in Japan reported that 72.5% parents worried about their kids, 82.3% parents felt tired in caring their kids, and 91.9% parents had no enough time well taking care of their kids. Although the survey data may vary from country to country or from region to region, it shows that caring kids is not an easy work and it does consume a lot of time/energy to many parents. In fact, parents have been putting lot of efforts to ensure their children’s safety. However, unexpected matters sometimes still happen. In other words, it is impossible for parents to keep eyes on their kids and give them prompt helps 24 hours a day. Fortunately, with the rapid advancing of ICT and ubiquitous computing, not only kids can enjoy the fruits of developments brought by IT like digital games, real time animations, multimedia contents, but also their parents benefit from the advanced technologies. This section presents the W2T based kid care platform on top of which kid care systems are built. With the support of kid care systems, parents benefit from the supporting systems and can be relieved more or less from their various worries regarding to kid cares, especially to those working couples.

The issue of kid care is important to a family but it is also an ordinary and common activity. It has not been receiving much attention from research communities although there have been some research going on [20,36,50]. Kids
as a specific group of human, it is necessary to have a thorough study. With
the rapid advancing of ubiquitous computing [5,56,57] and wireless commu-
ication technologies, developing kid care systems with ubiquitous sensors and
wireless communications become feasible. This research field has received in-
creasing attention. Based on related research results, we will develop a W2T
based kid care platform, as shown in Fig. 6, which can be described as follows.

To take care of a kid, the first step is to know the kid. A system has to first
record all the kid’s activities and get to know the kid by analyzing his/her
activities just like a parent is doing in the process of caring children. A kid’s
activities are recorded via SEA-nets in the physical world. The recorded data
are classified and stored in life-log, space-log, and thing-log, respectively. The
log data are transferred via the Internet/WWW and SEA-nets to the Unified
Log Data Center as shown in Fig. 6.

Each unified log database is a well-organized data structure and their re-
lationships are implicitly preserved and accessible in an organized relational
structure in the outer layer. To any situation in which a kid is, a node with its
branch in the structure corresponding to the situation represents a knowledge
set which is derived and composed from the log database. The knowledge set
about a kid and for handling a certain situation the kid is in, can be envisaged
as a grape branch, its structure varies from a situation to a situation.

The processes from being aware of a situation or a context to deriv-
ation of a knowledge set and from the knowledge set to provision of trans-
parent and active services to the kid are two important cores. The former
requires mechanisms to extract, retrieve, and analyze data/information in the
log database along the time axis or at a certain time section. The relational
data/information is linked in a way that a kid’s situation and context the kid
is in are represented either explicitly or implicitly. The relationships may be
expressed in an n-dimension relational matrix. To be aware a situation and a
context, a knowledge set can be dynamically composed together with history
situation-solution experience and new learning. Based on the derived knowl-
edge set, the system provides transparent and active services to the kid. For
instance, providing a warning message if the kid is in a dangerous situation,
informing his/her parents if the kid has fever, or reminding the kid to study
when he/she has been playing game all the time, locking the door if the kid
forgot, etc. To sum up, the system supports kid care from all aspects, safety,
health, education, security, etc.

From acquisition of raw data via SEA-nets in the physical world to the pro-
vision of active services in the cyber world to kids in the social world, it is a
complete data cycle. Kids (in the social world), things (in the physical world),
and computer systems (in the cyber world) are actually integrated an entity.
Their harmonious and symbiosis is realized by using the W2T including SEA-
nets, IoT, WoT, Hypw-DKServer, and Hypw-TSBus to guide a highly effec-
tive “Things-Data-Information-Knowledge-Wisdom-Services-Human-Things”
cycle.
5.3 The W2T based depression data center and diagnosis-recovery platform

Depression, one of the most prevalent disorders in the population, is a huge public-health problem. It is a chronic, recurring and potentially life-threatening illness that affects up to 20% of the population across the world. An estimated 20% of the general population will suffer depression sometimes in their lifetimes. About 15% of patients with a mood disorder die by their own hand, and at least 66% of all suicides are preceded by depression. Depression is expected to be the second leading cause of disability for people of all ages by 2020 [40, 61]. The increasing of depressed patients will burden the family and society heavily. Even if treatment with medication and/or electroconvulsive therapy (ECT) and psychotherapy are performed, it is still a long-term process which needs the support of information technologies. This section presents the W2T based depression data center and diagnosis-recovery platform on top of which depression diagnosis-recovery systems are built. These systems can provide various supports for depression prevention, diagnosis, therapy, care and recovery.

Depressive symptoms are characterized not only by negative thought, mood, and behavior but also by specific changes in bodily functions (for example, crying spells, body aches, low energy or libido, as well as problems with eating, weight, or sleeping). Neuroimaging studies [8, 22, 46] also found that the abnormal activity for depressed patients in brain regions including prefrontal, limbic, cingual, subthalamus, hippocampus, amygdala, as well as globus pallidus. Depression is usually first identified in a primary-care setting, not in
a mental health practitioner's office. Moreover, it often assumes various disguises, which causes depression to be frequently underdiagnosed.

Though clear research evidences and clinical guidelines have been found, treating depression is still a long-term and hardy process which cannot be completed only depending on hospitals, physicians and nurses. The depression prevention, diagnosis, therapy, care and recovery need the support of ubiquitous computing and wireless communication technologies. This research field has received increasing attention. Based on related research results, we will develop a W2T based depression data center and diagnosis-recovery platform, as shown in Fig. 7, which can be described as follows.

Treating depression needs the cooperation among hospitals, brain research institutions, families and society. The first step is to timely gather multi-aspect data of depressed patients or latent patients, including medical data obtained by hospitals, brain activity data obtained by the brain research community, and other health-related data, such as mood, behavior, physical symptoms, recorded by sensors or people around patients in the health-care pervasive service community. As shown in Fig. 7, these data are transferred via the Internet/WWW and SEA-nets to the Depression Unified Data Center.

Multiple types of databases are included in this data center. Some store structured data with a well-organized data structure and implicit or explicit relationships. Others store multimedia data with semantic and well-organized metadata. The derived multi-granularity information and knowledge are also organized and stored in this data center.

The processes from gathered data/information/knowledge to the provision of transparent and active services are diversiform because of different requirements of depression prevention, diagnosis, therapy, care and recovery. For monitoring of latent patients, their behavior modes are extracted from data to find physical symptoms and provide active reminding services by SEA-nets. For diagnoses of depressed patients, intelligent data query services are provided to integrate multi-aspect information, including mood, behavior, brain activities, and present/history medical treatments, for assisting diagnoses in hospitals. For treatments of depressed patients, mild patients can join the health-care pervasive service community to obtain transparent and active treatment/care services out of hospitals. Even if unexpected incidents happen on patients, physicians on vacation can give treatment programs and provide treatment services by ambulances. All of these services are integrated in a depression transparent service platform and published by the Hypw-DKServer and the Hypw-TSBus on the top of IoT/WoT, as shown in Fig. 7.

It is a complete data cycle from acquisition of raw data via SEA-nets, brain detecting equipments, physicians, and families in the physical world and social world to the provision of active services in the cyber world to patients in the social world. Depressed patients (in the social world), things (in the physical world), and computer systems (in the cyber world) are integrated into an entity to realize their harmonious and symbiosis by using the W2T to implement a highly effective “Things-Data-Information-Knowledge-Wisdom-Services-Human-Things” cycle.
6 Conclusions

With the development of advanced information technologies, especially IoT related technologies, a hyper world is emerging and will integrate the social world, physical world and cyber world. Data will be the vital medium of the hyper world. Through the WoT constructed on the IoT, data “run” in the hyper world with multiple formats, including information and knowledge, to tightly connect various human, computers and things, which are dispersed in the social world, physical world and cyber world.

The existing intelligence technologies of Web and ubicomp have focused on the conversion and utilization of data to provide more intelligent services on the Internet/Web or SEA-nets. However, these studies are limited in specific technologies, applications, data, and data conversions. Only using these technologies cannot fully utilize the enormous data and realize a holistic intelligence for the harmonious symbiosis of human-computers-things in the hyper world.

Integrating the existing studies of intelligent information technologies, this paper proposed the W2T as a holistic intelligence methodology in the hyper world. A W2T data cycle system is designed to drive the “Things-Data-Information-Knowledge-Wisdom-Services-Human-Things” cycle for realizing the W2T. This is a practically technological way to realize the harmonious symbiosis of human-computers-things in the emerging hyper world.

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