Cyber Physical Society

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Abstract—**Natural physical space provides material basis for the birth and evolution of human beings and civilization. The progress of human society has created the cyber space. With the rapid development of information technology, the cyber space is connecting physical space, social space and mental space to form a new world** — **Cyber Physical Society. The way to explore the cyber physical society is different from the way to explore the natural physical space and society. This paper describes the ideal of the Cyber Physical Society, and presents its distinguished characteristics and scientific issues. Research on the Cyber Physical Society could lead to the revolution of society, science and technology.**

I. INTRODUCTION

Human beings will live and develop in a new world—Cyber Physical Society, which concerns not only the cyber space and the physical space but also socio space and mental space.

The following are some early visions about the Cyber Physical Society.

In 2002, the notion of knowledge flow was proposed for connecting humans, minds, and knowledge transmission devices as well as controlling the process of knowledge sharing: *Team members are linked to various types of "knowledge transmission belts". Team members can put knowledge onto a proper belt, which then automatically conveys knowledge to team members who require knowledge. Any team member can get the required knowledge from the belt linked to him/her when performing task. Various knowledge transmission belts together with the team members constitute a knowledge flow network. The effectiveness of teamwork can be raised by properly designing the network and controlling its execution process* [16]. This is the early description of the ideal of the Cyber Physical Society. So far, we still do not know in-depth about the *knowledge transmission belts*, its form, mechanism and principle, although it objectively super-links human minds to support intelligent community.

Human cognition process and work processes are two inseparable parts of human problem solving, however, the cognitive process is neglected in most research on knowledge-intensive team Cooperation [8]. An approach for modelling these two parts of the process for a distributed co-operative team was proposed in 2003. The relation between knowledge flow network in mental space and the citation network in artifact space was further studied in 2005: *The implicit knowledge flow network in the citation network consists of knowledge flows between nodes that process knowledge, including reasoning, fusing, generalizing, inventing, and problem-solving* [18].

In 2003, virus in physical space, virus in cyber space, the Web, individual, society, and ecosystem health were linked in the background of fighting epidemics [17]: *Connecting nationwide systems through the Internet could create a worldwide eco-environment management service system that helps with collaborative monitoring, simulation, research, management, and control of epidemic situations. It should include globally distributed resources—devices, information, knowledge, and services—that could dynamically and intelligently collaborate to provide effective just-in-time services on demand to help manage an emerging crisis*. This ideal is in line with the notions of Web of Things or Internet of Things. In 2005, the effort to connect epidemic network in physical space and the cyber systems was made: *Rules of bio-epidemic and e-epidemic inspire scientists to create a live, scalable interconnected environment for effectively managing situations in the nature, society, and digital virtual world. Various sensors, networks, mobile digital devices, and robots extend the Internet to a pervasive interconnection environment that can automatically monitor and collect societal information to form an ideal environment for simulation* [19].

In 2004, the notion of future interconnection environment was defined from digital ecosystem point of view as follows [9]:

Eco-Grid is an open and worldwide interconnection environment with the characteristics of natural ecological environment. Versatile resources and social roles in the environment can harmoniously coexist and evolve, provide proper on-demand services for each other, transform from one form to another, and transmit in form of information flow, knowledge flow, and service flow under the principle of socio value chain. It keeps reasonable expansion of useful resources and can carry a certain pollution of rubbish resources according to the environment capacity. This can be regarded as the first scientific definition of cyber physical society and digital ecosystem. In the future, the natural ecology will be extended to the Cyber Physical Socio Ecology [15], where individuals and communities in different spaces could develop harmoniously.

The Knowledge Grid Methodology in [10] pointed out that: *Modern communication facilitates like the Internet provide people with unprecedented social opportunities for knowledge generation and sharing. However, our increasing computing power and communication bandwidth does not of itself improve this knowledge generation and sharing. The semantic ability of the facilities that transmit and store knowledge must be improved. Improving our social interaction would help enrich knowledge in our society by supporting social activities at different levels (both the physical and the mental level) and in different environment spaces. The Knowledge Grid is a virtual socio grid, where people enjoy and provide services through versatile flow cycles like control flows, material flows, energy flows, information flows and knowledge flows.* The methodology is also a valuable reference when developing the Cyber Physical Society.

In 2005, the notion of large-scale human-machine interconnection environment that unites the following three worlds was proposed in [11]: (1) *Physical world—nature, natural and artificial materials, physical devices, and networks.* (2) *Virtual world—the perceptual environment constructed mainly through vision and hearing, and to some extent touch, smell, and taste.* (3) *Mental world—ideals, religions, morals, culture, arts, wisdom, and scientific knowledge, which all spring from thought, emotion, creativity, and imagination.* This is actually a scientific definition of the Cyber Physical Society. The importance of harmonious development of the nature, society, environment and cyber world was emphasized as follows: *Networks pervade nature, society, and virtual worlds, giving structure and function to a variety of resources and behaviors. Discovering the rules that govern the future interconnection environment is a major challenge.* A set of parameters of the future interconnection environment was proposed. *Ideally, this environment will be an autonomous, living, sustainable, and intelligent system within which society and nature evolve cooperatively. It will gather and organize resources into semantically rich forms that both machines and people can easily use. Decentralized users will cooperatively accomplish tasks and solve problems by using the network to actively promote the flows of material, energy, techniques, information, knowledge, and services in this environment.*

Semantics is the core of the Cyber Physical Society as it is the basis of intelligent behaviours. The study of semantics should be carried out in real world, mental world, machine world and document world.

Since classification and link are two basic means to organize resources in these spaces, the Resource Space Model and semantic link network are two semantic models that are suitable for managing resources in cyber space, physical space, mental space and socio space [12][14].

The study of the mapping and integration between various semantic models such as Resource Space Model, OWL and database can help enhance understanding of these semantic models [20].

In 2010, the interactive semantics was discussed for the cyber society. The semantic world view, interactive semantic base, semantic image and semantic lens were proposed [13].

In April of 2010, the method of semantic networking in Cyber Physical Society and the interaction between spaces were further introduced in the keynote of IEEE AINA [14]. The term Cyber Physical Society was formally used to represent the ideal of future interconnection environment for the first time. A Socio-Natural Thought Semantic Link Network is proposed as the method for semantic networking in the Cyber Physical Society. The following is the basic notions: *Humans are able to observe and participate in social processes, to think, and to know the effect of establishing a relation. Humans can also actively select appropriate relations and persons according to requirement, situation and social rules. Machines are obviously limited in these abilities. Various graph-based models have been used to connect resources in the cyber space.* The following are two fundamental issues. *First, machines know little relation in human society and the nature, data structures in machines are for machines to process not for humans to read, so it is not realistic to expect machines to discover socio and natural laws and resolve relevant issues without human instruction. Second, machines are hard to know the effect of establishing and making use of relations, and to explain computing result according to society and nature. This is because machines do not have any worldview. Connecting various networks and machines with nature, society, and human minds can create a new environment where individuals have semantic images to enhance mutual understanding.*

The Cyber Physical Socio Intelligence was introduced in the keynote at World Computer Congress' IFIP AI2010.

II. GENERATION OF SPACES

The world evolves with separating new spaces from existing spaces. The following are some great separations:

(1) The separation of the mental space from the natural physical space. With the generation and development of human beings, individual mental spaces are gradually separated from physical human bodies. Individual mental space consists of thoughts (commonsense, concepts, rules, methods, principles, and theories) and imagination (derivation of links through thoughts). Individual mental spaces reflect each other, propagate through relations between individuals, and self-organize to reflect the mental space. As the effect of mental space development, an artifact space is gradually separated from the natural physical space. Humans' live is more and more in the artifact space and gradually away from the original natural space. Modern cities have been developing with including more and more artifacts.

(2) The separation of society from the natural physical space. Society is a space that contains socio individuals (humans and artifacts), socio relations between individuals, socio worth, authorities, and rules of human activities.

(3) The separation of symbol space from the mental space

and artifact space. As thoughts are invisible, more and more people use symbol languages to indicate and understand thoughts. Some symbol spaces are based on mathematical languages, while others are based on natural languages. Mathematicians have created many abstract spaces such as Euclidean space and Hilbert space. Humans have created a huge document space, which keeps expanding through times. Humans have the ability to link symbols to the mental space and to the physical space.

(4) The separation of cyber space from symbol space and artifact space. The cyber space extends the symbol space and artifact space to reflect more of other spaces. It not only enables humans to read documents distributed around the world but also facilitate communication and computation. Humans are making great efforts to extend and enhance the cyber space [3-5].

Different from other individuals, human bodies belong to the physical space, behaviours belong to society, and thoughts belong to mental space. Some artifacts like paintings are passive, but some like robots can behave according to programs pre-designed by humans. Humans have created various artifacts and cyber physical systems such as airplanes and robots [Cyber-Physical Systems Summit. *http://varma.ece.cmu.edu/Summit/*]. Airplanes can sense and record some flying data such as location, height, temperature, and fuel, and they have communication ability and can even autopilot according to pre-designed route and program. Space station and space shuttle are advanced cyber physical systems.

The Cyber Physical Society will go beyond the scope of the Cyber Physical Systems. It will fuse the spaces through various explicit interactions or implicit influence between spaces. Sciences, technologies and society will develop toward a harmoniously evolved cyber physical society.

III. INTERACTION BETWEEN SPACES

A. *Interaction*

The cyber space receives information from the physical space, mental space and socio space. It can fuse information and then compute to provide information to humans or control individuals in physical or socio spaces, or influence physical or socio spaces. Computers can communicate with each other while computing. Computers can send information to artifacts like robots and control their behaviors. Minds receive, process, and send information in mental space. Minds generate knowledge flows within minds for thinking and through minds for cooperation.

Future sciences will not only concern the principles in one space as physics and chemistry but also concern their influences in the other spaces and the principles cross spaces.

Sciences, technologies and society will develop towards a harmoniously evolved cyber physical society through appropriate interactions between spaces.

B. *Semantic Images*

The cyber space will contain semantic images of society, mental space, physical space, and itself [13]. The semantic space can have the following layers:

(1) *reflection layer*, e.g., images and videos;
(2) *commonsense layer*;
(3) *concept layer*;
(4) *rule layer*;
(5) *method layer*;
(6) *principle layer*; and,
(7) *theory layer*.

Interactions among semantic layers generate and develop thoughts. A phenomenon of falling apple leaves semantic images at the reflection layer (e.g., photo or video), at the commonsense layer (e.g., apple is fruit), at the concept layer (e.g., physical concepts: force *f*, the mass of an object *m*, and acceleration *a*, as well as gravity), at the rule layer (e.g., rule of multiplication), at the method layer (e.g., the multiplication operation), at the principle layer (e.g., *f=m·a*), and at the theory layer (e.g., physics).

The cyber physical society will extend the ability of humans to reflect the natural physical space, to conveniently interact with each other, to classify/cluster/locate in artifact space, to search/surf/zoom in cyber space, and to locate/reason/navigate in mental space.

A falling apple in physical space will be able to link to different semantic layers in cyber space, which incur relevant thoughts will emerge in mental space.

C. *Dimensions*

The cyber physical society has three essential dimensions. The first dimension consists of two facets: *thought* and *individual.* Individual is the abstraction of natural resources, humans, and artifacts. The second dimension consists of four facets: *time*, *space*, *relation* and *worth* [11]. The third dimension consists of four facets: *classification*, *interaction*, *influence*, and *transformation*. Classification is a basic mechanism to recognize, organize and manage individuals. Interaction is a process of physical action and reaction, socio behaviors, thought exchange or information transmission that changes the statuses of participated individuals. Influence is one-way while interaction is two-way. Both interaction and influence do not change the form of individuals but transformation does.

IV. SUPER LINK NETWORK

A. *Super-link*

Different from previous notions of Web of things, Internet of Things, and cyber physical systems [2][19], the Cyber Physical Society will be equipped with *super-links* to facilitate interaction through spaces.

(1) *MCM: Mental Space $\longleftrightarrow$ Cyber Space $\longleftrightarrow$ Mental Space*. Humans can communicate with each

other through symbols, but symbols are only indicators of thoughts rather than thoughts themselves. The future cyber space will reflect more and more semantic images of thoughts, so interaction between minds through cyber space will be realized by designing an appropriate man-machine interface (including bio-interface) and interaction process through spaces.

(2) *MCP: Mental Space* ⟷ *Cyber Space* ⟷ *Physical Space*. Humans can obtain the images of physical space through cameras and sensors, but the current cyber space is limited in ability to enable minds to freely interact with physical space even with the help of robots. A wrong notion is that cameras or sensors can connect cyber space to the physical space, and that cyber physical society is an application of sensor networks. Actually, sensors can only reflect the surface features of particular facet of individuals. For example, a photo of cup does not tell us if it contains water, coffee or tea, and it is even harder to tell us the taste. A cyber physical society should enable semantic interaction between cyber space and physical space in real-time. Interactions between cyber space and physical space are semantics rich. For the artifact space, designers are the best person to know where, how many, and what types of sensors or actuators are needed to reflect a bridge's real-time status. For the natural physical space, scientists are the best person to decide where, how many, and what types of sensors or actuators are needed for a natural individual to reflect its real-time status.

(3) *MCS: Mental Space* ⟷ *Cyber Space* ⟷ *Society*. Humans can take photos and videos and then store them in cyber space. They can also write programs to run processes in cyber space, but the photos, videos and cyber processes cannot interact with the socio processes in society to achieve a certain goal. A new channel is needed to enable thoughts to interact with socio process through cyber space.

(4) *MAC: Mental Space* ⟷ *Artifact Space* ⟷ *Cyber Space*. Humans make artifacts, and can watch them through cyber space, but they cannot interact with cyber space through artifact space. For example, humans cannot interact with devices through paintings. The super-links will enable thoughts to interact with cyber space through artifacts. New types of materials are needed to self-represent artifacts.

B. *Cyber Physical Socio Super Link Network CPSocio-SLN*

Semantic Web is to create machine-understandable semantics in cyber space [3]. Semantic net is to express knowledge in cyber space [7]. Semantic link network is to reflect social relations in cyber space [14]. CPSocio-SLN reflects various relations and the dynamicity in the cyber physical society. It can take the following form: p_i—l:c→p_j, where p_i and p_j are individuals or classes in one or different spaces, l represents the semantic relation between two points, and c represent the type of content or material that can be transmitted from p_i to p_j. CPSocio-SLN has the following distinguished characteristics:

(1) *Multi-spatial nodes*. A node in any space can link to any node in any space.

(2) *Diverse links*. Link can be of any type suitable for transmitting a certain type of information and influence can be in or through spaces.

(3) *Cross-space real-time influence*. Change of node or link will influence the linked node in real-time. Such influence can cross spaces.

C. *Interaction through CPSocio-SLN*

Humans wave CPSocio-SLNs consciously or unconsciously in lifetime from generation to generation. CPSocio-SLNs evolve and dynamically reflect semantics through operations. The evolution forms semantic communities (i.e., patterns). A key operation may transform patterns. The effect of operation on the network can be estimated. Interactions form temporal interaction nets through the networks. Super links enable interactions to pass through spaces, for example, text or image of apple in cyber space can link to the apple in supermarket or on an apple tree through sensors, and can further link to the physical concepts like gravity. The cyber physical society concerns both category and individuals: One tree will be different from the other tree, and one apple will be different form the other apple. Connecting these spaces can answer *what*, *where*, *why*, *when*, and *how* from different spaces in cyber physical society [14].

Hyperlink enables any Web page to connect to any other page. The semantic link connects semantic nodes in a certain relation that satisfies a certain rules on relations. Rules can be classified into different categories. It has the following three major characteristics:

(1) *Reasoning ability*.
(2) *Evolution ability*. A network may change if removing a previously added link.
(3) *Operation order sensitive*. Different orders of operations may lead to different results. The super-link can not only connect nodes in a certain relation but also interact and transmit content (denoted as c_i) according to the interests of nodes and physical or chemical rules. Rules of super-link will not only concern relations but also nodes. The physical principle and socio principle will be about both nodes and links. They will influence the evolution of the network. Therefore, communities of different types will form and evolve according to different socio laws. The closed loop of super-link network will raise the efficiency of making use of resources.

D. *Socio Influence*

In cyber physical society, different spaces obey different laws, but individuals in different spaces can interact with each other or influence one another. Influence occurs and propagates when individuals or links are added or removed. The influence of individual *A* on *B* through super link *l* can be measured by

the ranks of *A* and *B*, the rank of *l* and the times of effective interactions between *A* and *B*. Socio influence can be measured according to the extent of transforming the pattern of a CPSocio-SLN. The extent can be measured by the number of individuals who change their communities or obviously change the behaviors of certain number of individuals due to influence. Socio preference influences the formation of patterns.

E. *Socio Energy*

An individual has *potential energy* in socio network $E_p(x)$, which can be measured by its centrality in the socio network considering the times of interaction through its links. The potential energy of a community can be measured by its population and density considering both structure and interaction. The potential energy of an event can be measured by the number of involved individuals and the centrality of individuals.

Physical motion, socio behaviour, or cyber operation has *motion energy*. An operation's motion energy can be measured by E_p(*operation*)= *Number of individuals who have changed their community / Total number of individuals*. The CPSocio motion energy originates from thought in mental space. History tells us that a great thought can transform a society. The motion energy of operation is sensitive to operation order.

The following are two emerging principles in CPSocio-SLNs:

(1) *The node with rich types of links takes the priority to emerge*. The node with richer types of links takes the priority to emerge than that with less or single type of links. This is because the node with richer types of links offers higher probability to the new link to derive out more links so that communities have higher probability to be enhanced or changed. The new link has higher probability to connect the same type of link to transmit materials or contents. The reasoning rules on links determine the preference rather than as simple as 'the rich get richer'.

(2) *The path with single type of links takes the priority to emerge than that with more types of links when understanding or explaining the semantic path.*

The potential energy and the motion energy co-exist and co-evolve the cyber physical society.

V. REVOLUTION

The following are some revolution aspects of the Cyber Physical Society:

(1) *Science*. Thoughts' formation in individual mental space and propagation among mental spaces will have semantic images in the cyber space, so do research activities in physical space and socio space. Scientists will be able to access research objects and thoughts as well as their formation processes on demand through times. This means that they can not only communicate with peers but also access the thoughts of scientists in history. They can not only use language to express achievements but also link contents in paper to the process of research, and to possible applications. This requires new form of publication and therefore leads to revolution of publication. Scientific thoughts will efficiently influence society through the super-links to applications.

(2) *Education*. Students can learn natural and socio laws not only from linguistics and mathematical description in textbooks but also from the super-linked physical phenomena or socio events through times. How to sense various events is a challenge issue. Knowledge is formed, enhanced and rebuilt through interaction between coherent motions in four spaces. Question answering can be explained in different spaces [14].

(3) *Engineering*. Engineers can link artifacts to the manufacturers, to the ideas, to the design processes, and to the manufacturing processes. The statuses of artifacts (e.g., bridges) can also be monitored in lifetime so that necessary maintenance can be carried out on time to ensure healthy status. Function, structure, designer, owner, developer, and even economic, ecological and socio effects will be accessible. All spaces will cooperatively reflect the formation processes of artifacts when they are required, designed, built, sold, used, and recycled [15].

(4) *History and culture*. Individuals, family trees, thoughts, and socio events will be reflected, and be preserved as semantic images that can be accessed through times. Evidences of historical and cultural research will be easily available. Both material culture and non-material culture will be preserved. Recommendation or evaluation will be explained from historical and cultural point of view. Science fiction will not only exhibit imagination in text and in cyber space but also super-link to history and culture.

(5) *Society and life*. Society will be safer and life quality will be higher as the status of key individuals (e.g., people, socio facilities like bridges, and production sites like underground mining), communities, and events will have semantic images that can help make precaution. Health of individuals can be detected and evaluated on time, and evaluation results can be super-linked to measures. Evaluation result will be super-linked to socio influence through time. Cyber physical society will also help individuals fulfill the meaning of life.

(6) *Green society*. Cyber physical society will be efficient and low carbon as it will ensure optimal coordination between knowledge flow, information flow, material flow, energy flow and value flow through spaces. The cycle between consumption and production can be established to minimize the waste of material and energy with awareness of the super-links between materials, socio requirements, innovation, influence, production, and physical space. The

energy cost of computing will be taken into account in multiple spaces rather than just in cyber space.

(7) *Human-centered environment.* Current environment monitoring relies on fix point sample collection which only reflects general situation. Micro-environment around humans is important to human life, but it is hard to get as humans always move in daily life. In cyber physical society, the dynamic human-centered micro-environment will be aware by attaching sensors that can detect micro-environment and location to mobile phones and vehicles, collecting real-time information, and classifying information according to the location and density of people and pollution sources. The Cyber Physical Society will help people know pollution sources, avoid pollution, and take appropriate control measures according to dynamic micro-environment and recommendations.

(8) *Interactive virtual presence.* Children at home can feel the presence of their parents who are not at home through multiple types of super-links, and parents can know the situations around children, especially when special events occur. Senior peoples can feel the presence of their children and relatives who live in different places. Patients in rural areas can see doctors in major cities.

(9) *Energy and traffic.* Energy supplies will super-link to requirements, road maps, real-time traffic situation, parking spaces, and environment status. Traffic jam will be avoided based on certain socio priority and real-time situation. Vehicles can be guided to appropriate parking according to intentions and minimization of energy consumption.

The revolution of cyber physical society will also bring serious security issue. As human behaviours will influence the physical space and the society through the cyber space, the security will be cross spaces. Another issue is how to keep a reasonable expansion of cyber space so that it can harmoniously evolve with the society otherwise it may form negative influence on the society. These issues also bring research challenges.

VI. DISTINGUISHED CHARACTERISTICS

The Cyber Physical Society has the following major distinguished characteristics:

(1) *Real-time multi-space situation aware.* Life Web pages will be the first stage immigrated from the Web to the Cyber Physical Society. Photos in personal Web page will become real-time multi-dimensional senses like time, location, event, audio and video about the person. People with different privileges can view information from different dimensions and different scales. Further, the individual to be viewed can know the viewer, sense the viewer, and further presence virtually to events. Resources in different spaces can be self-organized in a multi-dimensional classification space.

(2) *Super-link.* Cues are usually local and not explicitly expressed, e.g., in text. Hyperlink explicitly displays the cues not only in text but also cross texts. Semantic links extend hyperlinks by attaching semantic indicators on links and assigning rules to regulate relational reasoning. Super-links will be interactive CPSocio channels [14], which will be able to transmit material, content and control information to realize real-time interaction between individuals cross spaces.

(3) *Multi-space health evaluation.* As individuals will live with multiple spaces, unhealthy individual or community in once space will influence the health of individuals or communities in other space. For human individuals, influence of unhealthy or sub-healthy will come from socio, mental, natural, and cyber spaces. Health should be detected and evaluated from multiple spaces.

(4) *Cross-space coordination through times.* The inclusion and effect of mental space and socio space distinguishes cyber physical society from the Internet/Web of Things and Cyber Physical Systems. Human individuals can know their own statuses when interacting with others. The statuses include their health, current micro physical space, socio attributes, the individuals who were or are trying to super-link and their status, their socio energy (including potential energy and motion energy), and the lifetime semantic images of individuals under access control.

(5) *Pervasive undetermined interaction.* Different from control processes and computer algorithms, Cyber Physical Society works with pervasive interactions between individuals within and cross spaces. More importantly, interactions follow rules in different spaces, and cannot be pre-designed.

(6) *Multiple semantic layer reflection and lifetime preserving.* The Cyber Physical Society will reflect individuals, communities, interactions and events at multiple semantic layers and link semantic elements in different layers. Different from digital archival, the cyber physical society's preserving is real-time, lifetime, and at multiple semantic layers.

(7) *Triangle reasoning/navigation + orthogonal locating + zooming.* Human memory network uses a kind of triangle-based grid cells for navigation in mental space [1], while humans often use orthogonal space (e.g., latitude and longitude) to locate an object in physical space. In cyber space, zooming is an effective means to navigate at different view levels and reduce the scope of destination. The Semantic Link Network uses the triangle reasoning and navigation [14]. Semantic communities at different levels support zooming on semantic link network to obtain semantic views of different abstraction levels. The Resource Space Model locates resources in the orthogonal classification space and supports zooming on classification hierarchies [12]. The integration of the two models supports navigation

with the features of triangle reasoning/navigation, orthogonal locating, and zooming in cyber physical society.

(8) *Humans' key role*. Humans wave and maintain super-links between spaces, evaluate and evolve socio values, and make final decisions to change personal statuses and to influence the evolution of the spaces in Cyber Physical Society at certain probability.

VII.   SCIENTIFIC ISSUES

With the fusion of physical space, mental space, socio space and cyber space, sciences and technologies specific to single space will be fused to form a systematic theory and method for studying and developing the cyber physical society. Techniques for the cyber space such as Web X.0, sensor networks, semantic web, service computing, peer-to-peer, agent, robotics, embedded systems, and automatic control will be fused to develop the infrastructure of the future cyber space. Research on Cyber Physical Society will significantly influence current sciences and technologies. New sciences and technologies will emerge in the near future. The following are some scientific issues.

(1) *Methodology*. Natural sciences concern the structures of natural individuals and laws of natural systems. Many information technologies are based on or about past, e.g., software and hardware are pre-designed, information retrieval is to get past data, and the statistical approaches are based on past data. The cyber physical society connects not only physical space, socio space, cyber space and mental space but also past, present and future. New methodology should change the progress of science and technology, break boundaries of existing disciplines, and be more insightful and predictable on the influence on the nature, socio, humans and culture. The aim is a harmoniously evolved Cyber Physical Society and its sustainable development.

(2) *Ability extension through spaces*. Mechanisms that extend thoughts to the creation of artifacts. An idea will link to sketch, to design, and further to the process of production. This concerns modelling and mapping between physical space, mental space, cyber space and socio space.

(3) *On-demand services through multiple space fusion*. Different types of resources could be fused on demand to provide services through logistics of materials in physical space, artifacts in artifact space, information in cyber space, knowledge in mental space, human and financial resources in society. More importantly, logistic processes will leave semantic images in cyber space and can be adapted according to the change of demand.

(4) *Cyber physical socio laws*. Study concerns competition, symbiosis and cooperation laws among individuals and among communities in the evolution process of the Cyber Physical Society [6], as well as laws of

networking, evolving and influencing the super-linked CPSocio networks.

(5) *Principles of interaction, transformation and flows*. Research concerns the principles that individuals in different spaces interact with each other, transform from one form into another, and coordinate through appropriate information, thought, service, material and energy flows. Principles, laws and methods of reflection, interaction, influence, and cross-space reasoning and explanation.

(6) *Reflexive, self-organized and self-adaptive architecture*. Cyber Physical Society needs a reflexive, self-organized, and self-adaptive cyber-physical architecture that can preserve semantic images of itself and various individuals in lifetime and manage various activities and processes (e.g., in nature, learning, creation and business). It enables socio activities and processes, physical individuals, thoughts as well as humans' physiological, psychological and mental status to be super-linked to create a panoramic interconnection environment for well-being.

VIII.   CONCLUSION

How our future world is like is a major concern of sciences. Above discussion can develop the notions of Eco-Grid and the future interconnection environment to the following ideal [9][11]:

Cyber Physical Society is a multi-dimensional complex space that generates and evolves diverse subspaces to contain different types of individuals interacting with, reflecting or influencing each other directly or through the natural, physical, mental, artifact, socio, and cyber subspaces. Versatile individuals and socio roles coexist harmoniously yet evolve, provide appropriate on-demand information, knowledge and services to each other, transform from one form to another, interact through super-links, and self-organize according to socio value chains. It ensures healthy and meaningful life of individuals, and maintains a reasonable rate of expansion of individuals in light of overall capacity and the material, knowledge, and service flow cycles.

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