

Ubiquitous Intelligence, Smart u-Things & World, Real World Challenges

Jianhua Ma

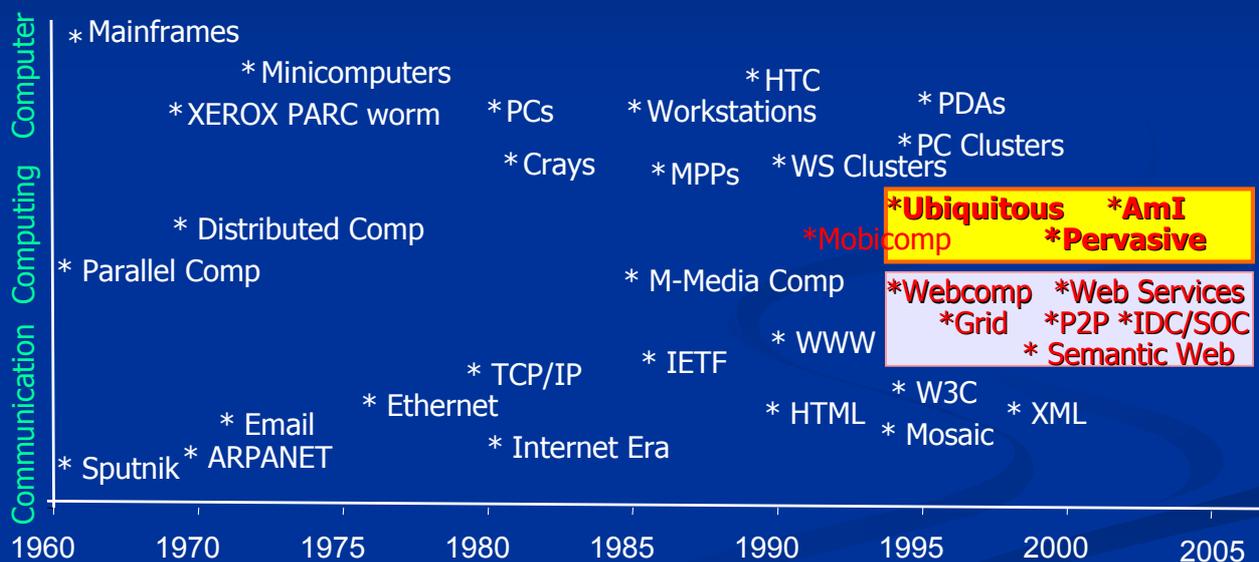
MUSE Lab (Multimedia Ubiquitous Smart Environment)

CIS, Hosei University, Japan

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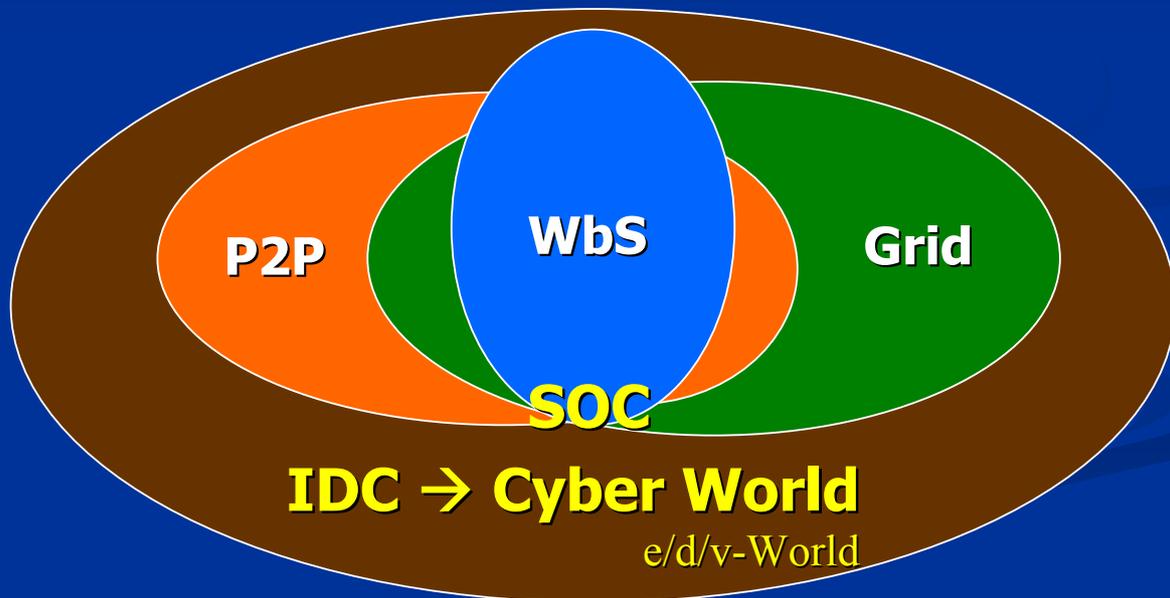
2005

Computer, Computing and Communication Tech. Evolution



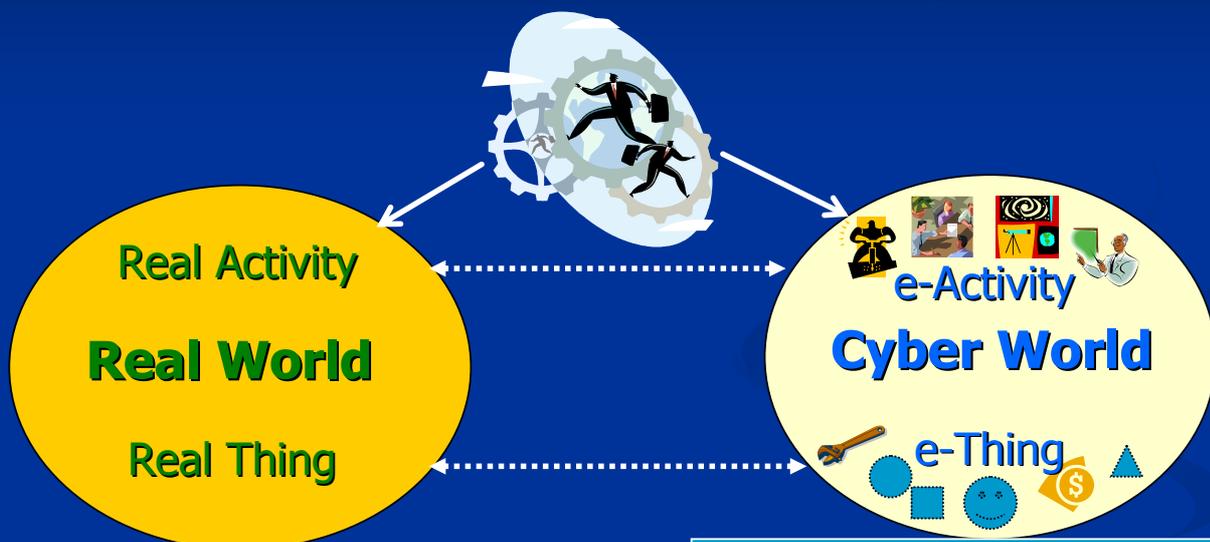
IDC/SOC: Intersection of WbS, P2P, Grid

- Internet Distributed Computing (IDC), Service Oriented Computing (SOC)
- unified and common platform of Web Services, P2P, Grid computing, etc.



Cyber Computing: e-Thing & e-Activity

→ Cyber World - Built on web/cyberspace in digital/virtual form



Web, WbS, Grid, P2P, Agent, Sem., etc.

Computers & Networks/Internet

International Conference on Cyber Worlds (CW)
(co-founder, since 2002)

Weiser's Vision (1990): Ubiquitous Computing (UC, Ubicomp)



Mark Weiser
(1952-1999)

1988: Notion „Ubiquitous Computing“

- Introduced and defined by Mark Weiser, XeroxParc
- ubiquitous „everywhere“
- Ubiquitous: economically, in arbitrary amount available

1991 „The Computer for the 21st Century“

- Article in Scientific American
- Vision: Computers become so much of our daily live that we do not take notice of them any longer

Industry Vision (1999, IBM, etc.): Pervasive Computing (Percomp/Percom)

EU's Vision (2001): Ambient Intelligence (AmI)

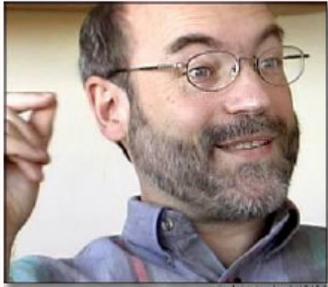
Ubiquitous/Pervasive Computing, AmI: Real Thing & Activity

Ubicomp/Percomp/AmI → Real world with digital enhanced real things



UC, ID, Context, Middleware, etc.	Web, WbS, Grid, P2P, Agent, Sem., etc.
Sensor/M/NEMS, Comps & Per. Nets	Computers & Networks/Internet

Real World Computing



„In the 21st century the technology revolution will move into the everyday, the small and the invisible..“

Mark Weiser (1952 – 1999), XEROX PARC

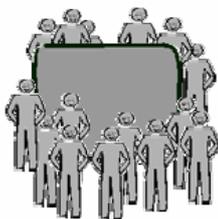
“Ubiquitous Computing enhances computer use by making computers **available throughout** the physical environment, while making them **effectively invisible** to the user”

Ubi-comp: a field on a physical world richly and invisibly interwoven with sensors, actuators, displays, and computational elements, embedded seamlessly in everyday objects of lives and connected through a continuous network.

- Mark Weiser in his last article in IBM Sys. Journal, 1999

Weiser's View – Three Relationships

The Place of computer technology in our lives...



m-to-1

Mainframe Comp.
many people share
a computer

Use must be well
prepared

“run by experts
behind closed doors”



1-to-1

Personal Comp.
one computer, one
person

direct explicit use

“while it may take you
where you want to go,
it requires
considerable attention
to operate”



1-to-m

Ubiquitous Comp.
many computers share each of
us

Use implicit (automatic)

“each person is continually
interacting with hundreds of
nearby interconnected
computers”

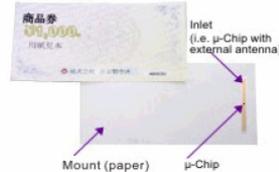
Trend One: Device Ministration - Tiny Chips and Micro-Devices -

μ - chip

- Size: 0.4 mm²
- Carrier frequency: 2.45 GHz
- Operating distance: 0-25 cm
- Memory capacity: 128bit ROM
- Anti-collision:
- Response time:

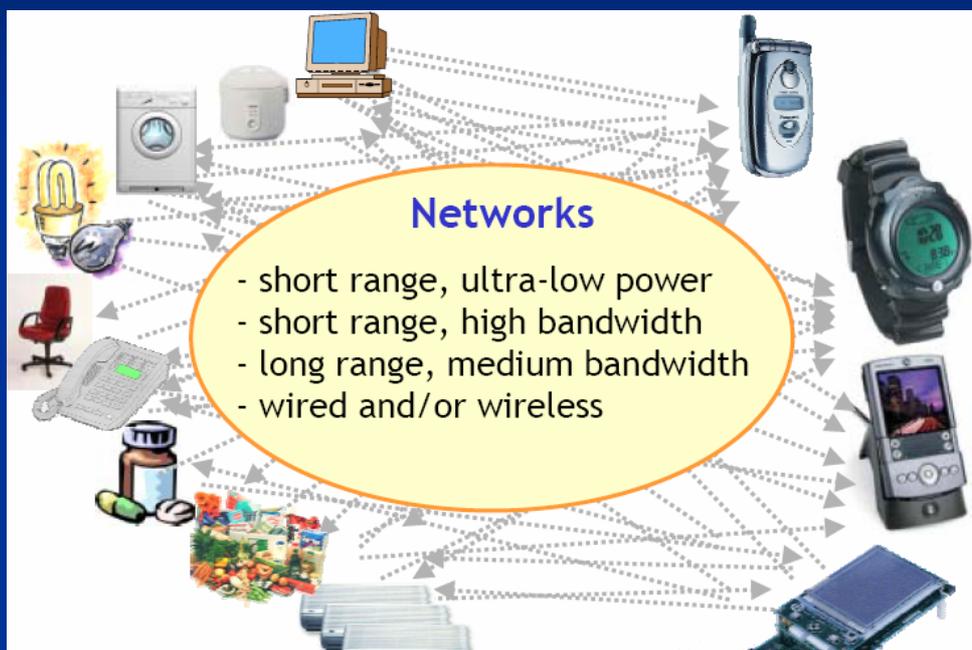
By Hitachi, 2003

Application Example: Gift Certificate



Small → Tiny → Dust → Invisible → Disappear
They are Attachable, Embeddable, Blend-able

Trend Two: Ubiquitous Communication - Wired & Wireless Pervasive Networks



All Things Connected → Able to Talk

Trend 3: u-Things' booming Attachment, Embedment, Blending

◆ Three fundamental Technology Trends

- Continuing miniaturization of electronic chips & electro-mechanical devices (Moore's law, new material, nanotech., ...)
- Various computers/devices → small → tiny → invisible
- Available interconnections by ubiquitous/pervasive networks especially using wireless communications
- All computers/devices → connectable → talk-able → interact-able
- Many real things can be integrated with attached, embedded, and/or blended computers, networks, and/or some other devices such as sensors, actors, e-tags and so on.
- **u-Things**: Real things with some kind of attachment, embedment, blending (**AEB**) of computers, networks, and/or other devices
- e-booming → u-booming*
- Following the above trends, what the future world will be?

Essential Questions

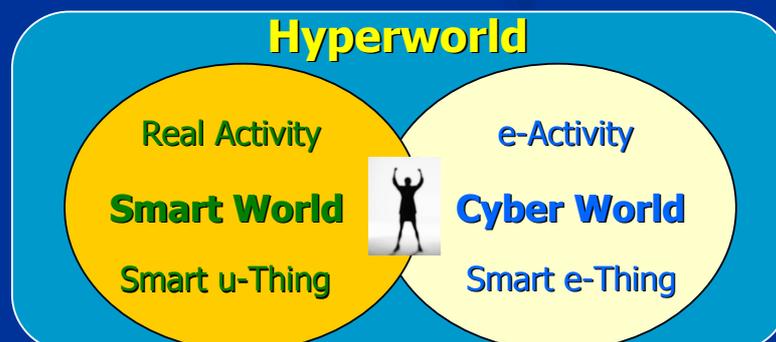
- Can machines think ? → AI
 - By A. Turing in "Computing Machinery and Intelligence" in 1950
 - He believes machines think and also believes that "at the end of the century the use of words and general educated opinion will have altered so much that one will be able to speak of machines thinking without expecting to be contradicted".
- Can things think ? → Intelligent real object
 - Consortium of Things That Think (TTT) in MIT Media Lab since 1995
 - "When things start to think" by Neil Gershenfeld of MIT in 1999.
 - Thing thinking means the thing has some intelligence.
- Can thinking things be everywhere ? → UI, Smart World (SW), AmI
 - Ubiquitous Intelligence (UI) or Pervasive Intelligence (π) since 2003 – by us
 - Being a fact/phenomenon of ubiquitous existence not only as methods/tools
 - Residing in everyday objects, environments, systems, ourselves, ...
 - Extending to both man-made and natural things
- Information Explosion → Intelligence Explosion !
 - The Intelligence Revolution, Interview by Wise Media, ID People Magazine, Apr./05
 - Ubiquitous Intelligence Summit 2005, A Think Tank, Oulu, Finland, June 15-17, 2005
 - Journal of Ubiquitous Computing and Intelligence (EiC), American Scientific Publishers

Intelligent Computing Waves

- **1st: AI (Logic/KL-based)**
 - Machine learning
 - NLP & Comp-Vision
 - Robot & game theory
 - Expert system
 - Knowledge/Reasoning
 - DAI (Distributed AI)
- **2nd: Soft/Natural Comp**
 - Probabilistic computing
 - Fuzzy logic
 - Neural network
 - GA/Evolutionary computing
 - Chaotic/Swarm computing
 - Biologic computing
- **3rd: Agent (Social Comp)**
 - Autonomous software
 - Multi/Massive agents
 - Agent language
 - Agent negotiation & cooperation
 - Personal/social behavior
 - Web intelligence/semantics
- **4th: UI (?) (Real things' intelligence)**
 - Physical/everyday things' intelligence
 - Atop of the above 3 intelligent comp
 - Scale,dynamic,heterogeneous,spontaneous
 - Predictable, controllable, adaptable, manageable, ethic, ...
 - Others-aware & self-aware → *mind/spirit?*

Hyperworld and Smart World

- **Hyperworld**
 - "Hyperworld Modeling", Keynote in VIS, Melbourne, Feb. 1996 (Kunii, Ma, Huang)
 - "Its basic characteristic is direct mapping between virtual and real worlds via active devices including sensors, actuators, micro-machines, robots, etc." - 1996
 - "A Study on a Hyperworld System of One-to-Many Interaction", ICAI'97 (1-to-m relationship)
 - "Towards Direct Mapping between Information Worlds and Real Worlds", LNCS1306, 1997
- **Smart World (SW)**
 - Based on ubiquitous computers, networks, information, services, etc.
 - Created in both real and cyber spaces
 - Characterized by ubiquitous intelligence in the real world
 - Pervaded with intelligent or smart ubiquitous things/u-things



Roads Towards Smart World & UI

- **Universal Identification**
 - RFID, E-Tag, AV/Biomedical
 - Location aware computing
- **Physical & Social Awareness**
 - Sensor networks
 - Context based computing
 - Privacy/trust computing
- **Digital Enhanced Object**
 - Embedded computing
 - Wearable/augmented computing
 - Everyday computing (*Georgia Tech*)
 - Sentient computing (*AT&T*)
- **Platform & Middleware**
 - WS, UPnP, Jini, SLP, OSGi, ...
 - Smart-Its, T-Engine, eTRON, ...
 - Aura, Gaia,, iROS, RCSM, MetaGlue, ...
- **Interface & Interaction**
 - Calm technology (*Weiser & Brown*)
 - Invisible/disappear computing
(*UoW, CMU, DARPA & EU*)
 - Palpable computing (*PalCom, EU FP6*)
 - Proactive computing (*Tennenhouse, CHI'04-P*)
- **Deployment & Management**
 - Sustainable pervasive comp (*SPC'04*)
 - Autonomic computing (*IBM, ICAC-04*)
 - Organic computing (*GI-Workshop'04, ARCS*)
- **Model & Design**
 - Massive multi agent (*MMAS'04, Kyoto*)
 - CW Axioms & Cellular Modeling (*Kunii*)
 - Amorphous computing (*MIT*)
 - Spray computing (*Zambonelli*)
- **Intelligent Environment**
 - Ambient intelligence (*AmI, AmI-03, IE-05*)

Smart u-things - Essential Elements in Smart World with Ubiquitous Intelligence

- **Smart Object (Smartifact)**
 - A physical object with AEB and some smartness/intelligence
 - *Device, card, label, sensor, artifact, appliance, goods, furniture, textile, robot,*
- **Smart Space/Environment**
 - A physical spatial environment integrating smart objects &/ usual devices
 - Smart services via these objects/devices and their commun./cooperation
- **Smart System**
 - May be a real system like a network, traffic system, ...
 - May be a platform middleware for a kind of smart object/environment
 - May be a general one supporting a class of smart applications

(Future) Ubicomp/Percomp → computing of smart u-things

1st Int'l Wksp on Ubiquitous Smart World (USW-05, Taiwan, March 2005)

2nd Int'l Sym. on Ubiquitous Intelligence & Smart World (UISW-05, Japan, Dec. 2005)

3rd Int'l Conf. on Ubiquitous Intelligence & Computing (UIC-06, China, Sept. 2006)

Smart & Smartness: Terms and Characters

➤ Smart related computing terms

- "intelligent"
- *Sentient, Aware, Context-aware, Active, Reactive, Proactive, Assistive, Adaptive, Automated, Autonomic, Perceptual, Cognitive, Thinking, Selfware, ...*

➤ Smartness features in general

- Some kind/level of intelligence, but softer, wider and flexible than "intelligence"
- From simple reactive functions to complex intelligent behaviors
- Anything from real to e/virtual ones, but with emphases of real/physical ones
- Felt relatively not absolutely → **two co-exist facets: smart and stupid!**
- Complicated or abstruse philosophical, culture social, ethical and other implications

➤ Ultimate goal of UI and SW

- To make u-things "*calm*" or behave **trustworthily in context-/self-awareness**
- To move Ubi/PerServices from **ANY** place/time/means to **RIGHT** place/time/means

➤ Smart u-thing challenges

- Technology Complexity: discussed widely and realized relatively well
- Real World Complexity: addressed rarely and realized not very well

Smart u-Things – Technology Challenges

➤ Three basic types of functions for smart u-things

- Computation & storage for processing and memory
- Networking & naming for interconnection and communication
- Sense & effect for perception and interaction

➤ Technology challenges (not exhausted)

Both in hardware and software → devices miniaturization, power management, sensor nets, universal ID, ubiquitous/pervasive networks, ad hoc mobility, open service architecture, sensed information overload & database, context semantics & management, autonomic system administration, user interface, operating system, language, middleware, integration, cooperation, scalability, heterogeneity, dependability, availability, security, privacy, test, evaluation, standards, etc.

"Global Ubiquitous Computing: Design and Science", UC Grand Challenge: Manifesto, UK, June 2005
Beyond-The-Horizon Workshop on Pervasive Computing and Communications (PCC), Vienna, July 2005

Smart u-Things – Real World Challenges

➤ Smart u-things are emerging

- Many scenarios: Weiser's Sal, AmI's Maria/Dimitrios/Carmen, Aura's Jane/Fred, ...
- Various prototypes but yet widely practical ones
- A highly possible boom of smart u-things in near future

➤ Ideal smart u-things expected

→ Able to act adaptively and automatically according to

1. Surrounding Situations

2. Users' Needs

3. Things' Relations

4. Common Knowledge

5. Self Awareness

6. Looped Decisions

➤ Above challenges from real world intrinsic characteristics

- RW == physical + social + natural + ... → **uncertain, unpredictable, changing, ...**
- RW computing: complicated/abstruse phil., social, ethical & other implications
- Understanding real world (RW) diversity and complexity → Extremely Hard !!
- Novel cyber dimensions newly added in physical/digital combined u-things

Challenge 1 – Situation Approximation

➤ Context

- Information characterizing the situation of an entity (Dey) or 5Ws (Abowd)
- Whole contexts are a collection of various values from sensors or other sources

$$C(t) = \{C_i(B_i, L, t_h), i \in I(t), t_h \in [t-h, t]\}$$

➤ Situation

- Relatively compact, more semantic, directly used for judgment/decision

$$S(t) = \phi [C(t)] = \{S_j(W_j, t), j \in J(t)\}$$

Designing a Context-aware System to Detect Dangerous Situations in School Routes for Kids Outdoor Safety Care, LNCS, Proc. of EUC'05.

➤ $C(t), S(t) \rightarrow$ approximations to a real environment

- Are the contexts $C(t)$ sufficient and precise enough to characterize a real environment?
- How correctly be $S(t)$ determined using available but incomplete & uncertain contexts?
- What are consequences of situation judgment errors to context-aware/situated u-things?

Nyquist Sampling Theorem & Shannon Entropy/ $R(D)$ Theory → Theory for context/situation?

→ **Keep incompleteness, uncertainty and misjudgment as basic design assumptions !**

Challenge 2 – Knowing Users' Needs

➤ Interactive Mechanism

- A request-response dialog process betw. users (activator) & computer (passive)
- 3 user limits: too small/many/complex computers to be visible/interact-able/manageable

➤ Proactive and Autonomic Mechanisms

- Take actions proactively by anticipating users' needs (Tennenhouse, Intel, 2000)
- Manage themselves under human supervisions/needs (Paul Horn, IBM, 2001)
"Proactive Control of Group Revision Assistance Management Using P2P Technology" (Takata & Ma, ISIT04)
Journal of Autonomic and Trusted Computing (JoATC, EiC), ASP, USA
1st Int'l Wksp on Trusted and Autonomic Ubiquitous & Embedded Systems (TAUES-05, Japan, Dec. 2005)
2nd International Workshop on Trusted and Autonomic Computing Systems (TACS-06, Austria, Apr. 2006)
3rd Int'l Conf. on Autonomic and Trusted Computing (ATC-06, China, Sept. 2006)

➤ Users' Needs

- Multi aspects and subtle affection by many factors

$$N(t) = \{N_{u,v}[P_{u,v}(t), S(t), S(t-\Delta)], u \in U(t), v \in V(t)\}$$

➤ Hardness of knowing users' true needs

- How much can be known correctly and promptly for users' true needs in changing situations?
- "Know you and know your face, but don't know your mind" - Chinese saw

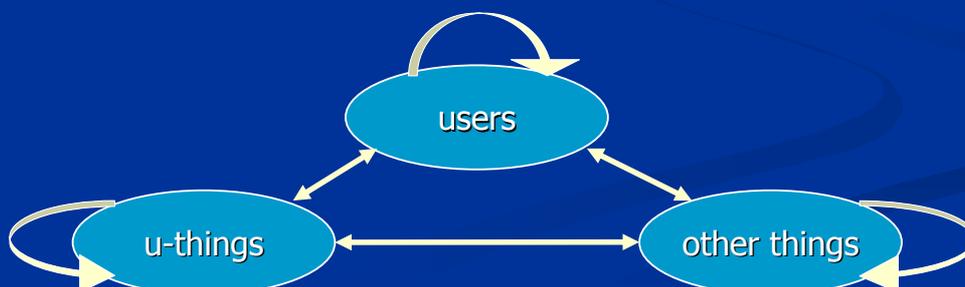
Challenge 3 – Complex Things' Relations

➤ Complex Relations among u-Things

- u-things are connected and interacted
- "Everything will be connected to everything else" - by R. Lucky, 1999
- **Cyber dimensions**, except spatial/temporal/other conventional dimensions
- Complex dynamic relations among users, u-things, and other things

$$R(t) = \{R_q(T_q, U_q, t), U_q \in U(t), q \in Q(t)\}$$

- How to define, find, describe and use complex relations necessary for u-things' systems?
Smart Hyperspace: a set of interconnected smart spaces with situational-spatial-temporal relations
("Modeling Interface with a Multimedia Hyperworld", HIS'96, "Smart Hyperspaces and Project Ubikids", USW05)



Challenge 4 – Common Knowledge

➤ Why common knowledge needed?

- Knowledge is the base of analysis, reasoning, anticipation and judgment (Ref AI)
- Smart u-things are in the physical environments and serve people's daily life and work
- Smart u-things need some common knowledge about physical world, human society, etc.

$$K(t) = \{K_m(F_m, t_h), m \in M(t), t_h \in [t_0, t]\}$$

➤ Issues are

- What knowledge is necessary for smart u-things?
- What knowledge should be initially set?
- What knowledge can be added later on?
- What knowledge may be self-learned during uses?
- How knowledge is used for rich and varied real situations?

→ Challenge - how to abstract, learn, use complex knowledge about human & world.

➤ How about DAI, swarm, softcomp, agent, semantics, etc.?

Challenge 5 – Self-Aware u-Things

➤ Why smart u-things should be self-aware

- Physical, not virtual, things with attached/embedded/blended (AEB) computers/etc.
- AEB devices are function parts or components of the real physical things
- AEB is for enhancing original functions of real things following common rules
- Smart u-things should be aware their roles and function without against the rules

$$A(t) = \{A_z(G_z, t), z \in Z(t)\}$$

➤ Context-awareness vs self-awareness

- Context-awareness: knowing others
- Self-awareness: knowing selves
- *"Knowing others is wisdom, knowing yourself is enlightenment" - Tao Tzu*
- What this exactly means? How to equip self-awareness to u-things?

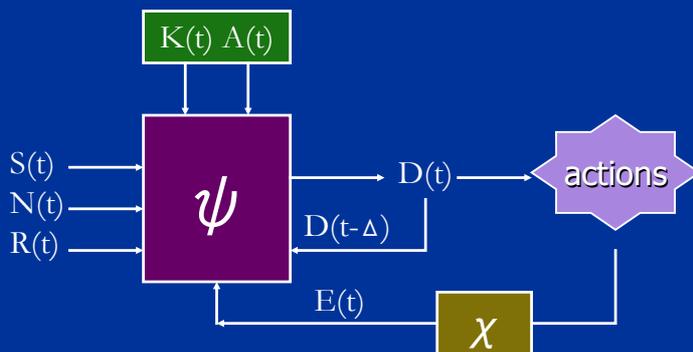
➤ Extreme Challenging and rare research

"we seem so ill equipped to understand ourselves", The Society of Mind, Minsky, 1986
Workshop on Self-Aware Computer Systems - Chaudhri & McCarthy, SRI/DARPA, 2004

Challenge 6 – Looped Decisions

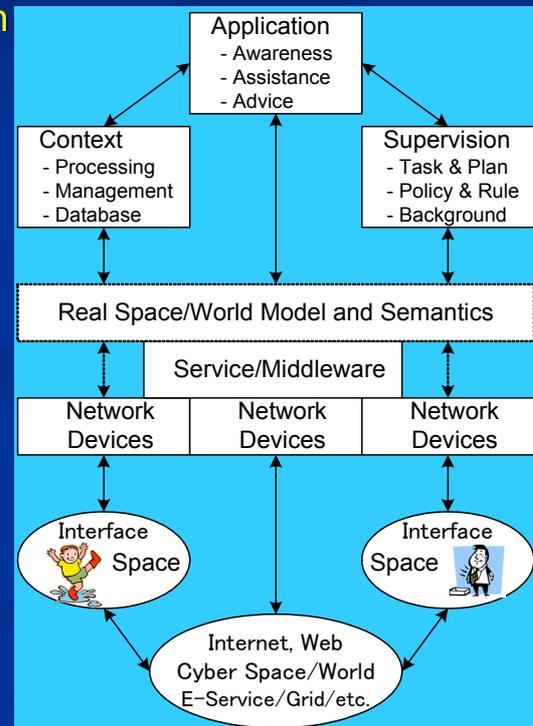
- Decisions cannot be correct always in 100%
- Imprecise decision & exception are common
- ➔ **Loop mechanism is indispensable !**
How many loops? Layered models?

$$D(t) = \psi [S(t), N(t), R(t), K(t), A(t), D(t-\Delta), E(t)]$$



- Challenge is how to adaptively correct errors & make necessary adjustments
- *How related to automatic control theory?*

UbicKids general architecture



Summary

- Trend toward Ubiquitous Intelligence (UI) & Smart World (SW)
- Smart u-things: essential SW elements → core of ubi/percomp
- RW complexity challenges in making u-things truly smart
 - To examine the possible hard issues to suggest some potential research lines
 - To let researchers in this field coolheaded and being aware of the hardness
- Weiser's words in his last days

"If the computational system is invisible as well as extensive, it becomes hard to know what is controlling what, what is connected what, where information is flowing, how it is being used, what is broken, what are the consequences of any given action. Maintaining simplicity and control simultaneously is still one of the major open questions facing ubiquitous computing research."

- IBM System Journal, Vol. 38, No. 4, 1999.

Our Research – Smart Hyperspace

- (Situational Principle) Context Awareness (Schilit et al, 1994)
- (Spatial Principle) Boundary Principle (Kindberg & Fox, 2002)
- (Temporal Principle) Continuous Interaction (Abowd et al, 2002)
- (Situational/Spatial/Temporal Principle) Interrelation (Ours, 1996, 2003)
Hyperworld Modeling (VIS'96), Modeling Interface with a Multimedia Hyperworld (HIS'96)
 - A present situation may be related to events in the past/future probably at other spaces
 - A current event may result in a sequence of follow-up events in different places/time
 - A user may frequently move between different spaces in daily activities
 - A user may be sometimes interested in what happen at other places in a particular time

Current status: focused on a variety of individual and isolated smart spaces
but seldom or without fully addressing space interrelations !

→ Need of smart hyperspace, interrelated & connected smart spaces!

Internet	→	Interconnect Networks
WWW	→	Interconnect Files
P2P	→	Interconnect Clients
Grid	→	Interconnect Resources
WbS	→	Interconnect Applications
Hyperspace	→	Interconnect Spaces

Smart Hyperspace Issues

- Hyperspace abstraction and model
- Hyperspace semantics and representation
- Connections of heterogeneous smart spaces
- Context interrelations and sharing across places/time
- Smoothness of uneven spaces or space jitters (smartness differences)
- Coordination and management of associated smart spaces
- Scalability and manageability of a hyperspace
- Security, privacy, and trust in multi-spaces
- Interface and Interaction of a hyperspace
- Hyperspace network infrastructure
- Hyperspace middleware and interoperations
- Hyperspace social/economic/cultural/ethic implications and impacts
- ...

No answer yet ! The issues themselves need to be further clarified !!

Two fundamental research ways:

- General thinking and systematic theoretical study is essential
- Proper and representative concrete case study is necessary

Why A Smart Hyperspace for Kids Care

- Scope Criteria
 - Includes a set of different but interrelated spaces capable of being smart
 - Covers core issues related to the smart hyperspace
 - Involves both technical and non-technical factors
- Feasibility Criteria
 - Complexity controllable and improvable continuously
 - Privacy relatively acceptable and can be enhanced gradually
 - Cost is reasonable, especially in the beginning
- Other Criteria
 - Useful
 - Novel
 - Fun
- A ubiquitous kids care system likely matches the above criteria.
A unique one comparable with Personalized Instrumented Health System for elders (PIHS, UR/MIT/GT/UF)
- A survey recently made in Japan, says 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 to satisfactorily take care of their kids.
- IT gifts to kids: toy, game, animation, what else are specially designed for them?
 - Lacks enough research and non-playable products for kids by IT
 - Interaction Design and Children (IDC, annual conference since 2002) – No kids care topics!
- Such system is not only proper for hyperspace study but valuable for a special type of users

UbicKids – Ubiquitous Care for Kids

- UbicKids Objectives
 - To develop a set of ubiquitous applications for assisting parents to take care of their kids with more convenient, prompt, reliable, precise, secure and trust services.
 - To build a representative smart hyperspace for probing and researching ubiquitous hyperspace related issues, models, technologies, etc.
 - To study impacts and solutions of non-technical factors to both ubiquitous systems and users, especially children, their growth, character development, etc.

- UbicKids Assumptions

- Usual family with one or more normal children (disabled, single par., grand par., ...)
- Typical spaces such as home, yard, park, street, station, car, school, office, clinic, ...
- Kids ages: ways in caring kids vary for kids in different ages, (families, cultures, ...)



- UbicKids Functions – 3A

- Kids **A**wareness: knowing kids current & past status
- Kids **A**ssistance: helping kids in doing something
- Kids **A**dvice: advising/reminding kids and parents

Towards a Smart World and Ubiquitous Intelligence: A Walkthrough from Smart Things to Smart Hyperspaces and UbicKids, Journal of Pervasive Comp. and Comm., 1(1), March 2005.

UbicKids - Non-Technical Factors

Double-edged Sword

- Seamless integrations of physical and digital world,
- “a strange new world” (by Mattern, 2004)
- Kids learn from everyday interactions with the environments
→ help forming their characteristics, behaviors, habits, personalities etc.,
→ influence their whole lives.
- A truly useful UbicKids system
→ full considerations on non-technical factors, i.e., human, society, culture, physiology, psychology, moral, feeling, etc.
- Positive and negative impacts to kids
→ be seriously investigated
→ solutions must be discovered to overcome the negative aspects.

Non-Technical Factors

- Common characteristics shared by many kids
- Special characteristics for individual kids
- Characteristic changes along with growing kids
- Relationships and roles of family members
- Features of kids care activities
- Heterogeneity in kids care
- Cultures and laws in kids care
- Psychological behavior in a smart space
- Child's personality development
- Child's habit and moral cultivation
- Child's independence improvement
- Child's intelligence increase
- Feeling/love enhancement of parents-kids
- Special care to disabled/incapacitated children
- Family of single parent, with nurse, etc.
- ...

Final ...

Care some special “kids”: dog, cat, ... (pets)!

→ *UbicPets, Ubic~ ?*

→ *Ubi-others?*

From virtual *e-things* to *m-things* to real *u-/p-/s-/i-things*

e-, e-, e, ... → *m-, m-, m-, ...* → *u-, u-, u-, ... ?*

→ *p-, p-, p-, ... ?*

→ *s-, s-, s-, ... ?*

→ *i-, i-, i-, ... ?*

Lesson: → \mathcal{E} (concrete/small) → ∞ (general/great)

What's Ubi-next ? → Beyond Ubi/Per/Am- !