Challenges in Design and Implementation of Mobile/Ubiquitous Computing: A Socio-technical Research Agenda

IFIP TC 8 WORKING CONFERENCE, OSLO
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Agenda

- Enter the new environment
- Examples of ubiquitous applications
- Research Framework and Research Challenges
- Emerging Research Issues and Examples of Research Studies
- Conclusions

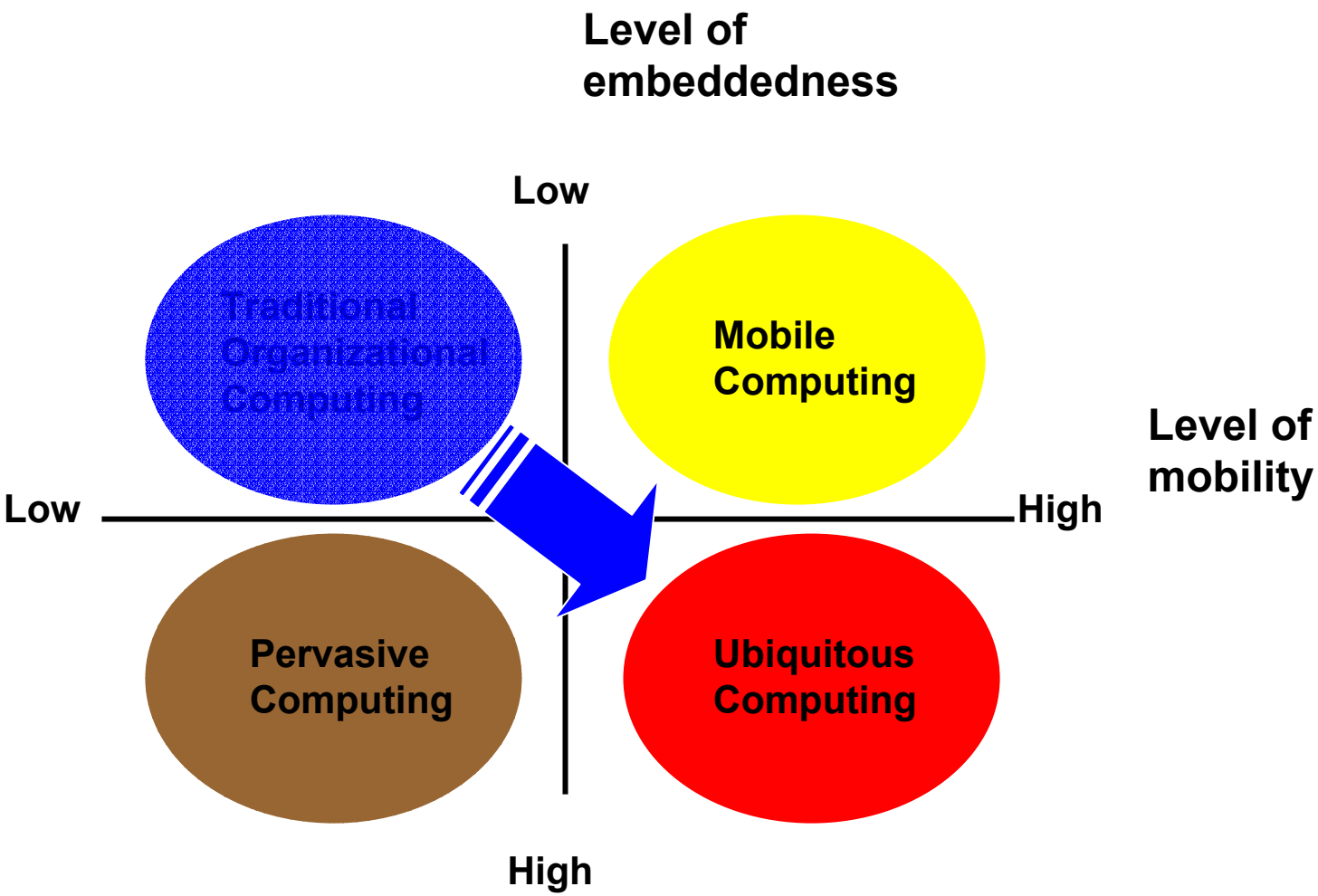
Ride the technological waves

1970- The wave of mainframe computing	Large scale transaction systems, Business Automation and effectiveness
1980- The wave of microcomputers	Personal support, office automation of clerical tasks
1990- The wave of network computing (Internet)	Universal information access, electronic commerce, group applications
2000- The wave of digital convergence and net-centric computing	Any time, any place digital services, service integration, peer-to-peer computing, context dependency

Definitions

- Ubiquitous Computing: An assemblage of interconnected technological elements embedding computing services into our natural movements and interactions with the environments - both physical and social.
- Technology factors
  - Wireless technology
  - Miniaturization of chips
  - Developments of handheld devices and sensors

Movement to Ubiquitous Computing



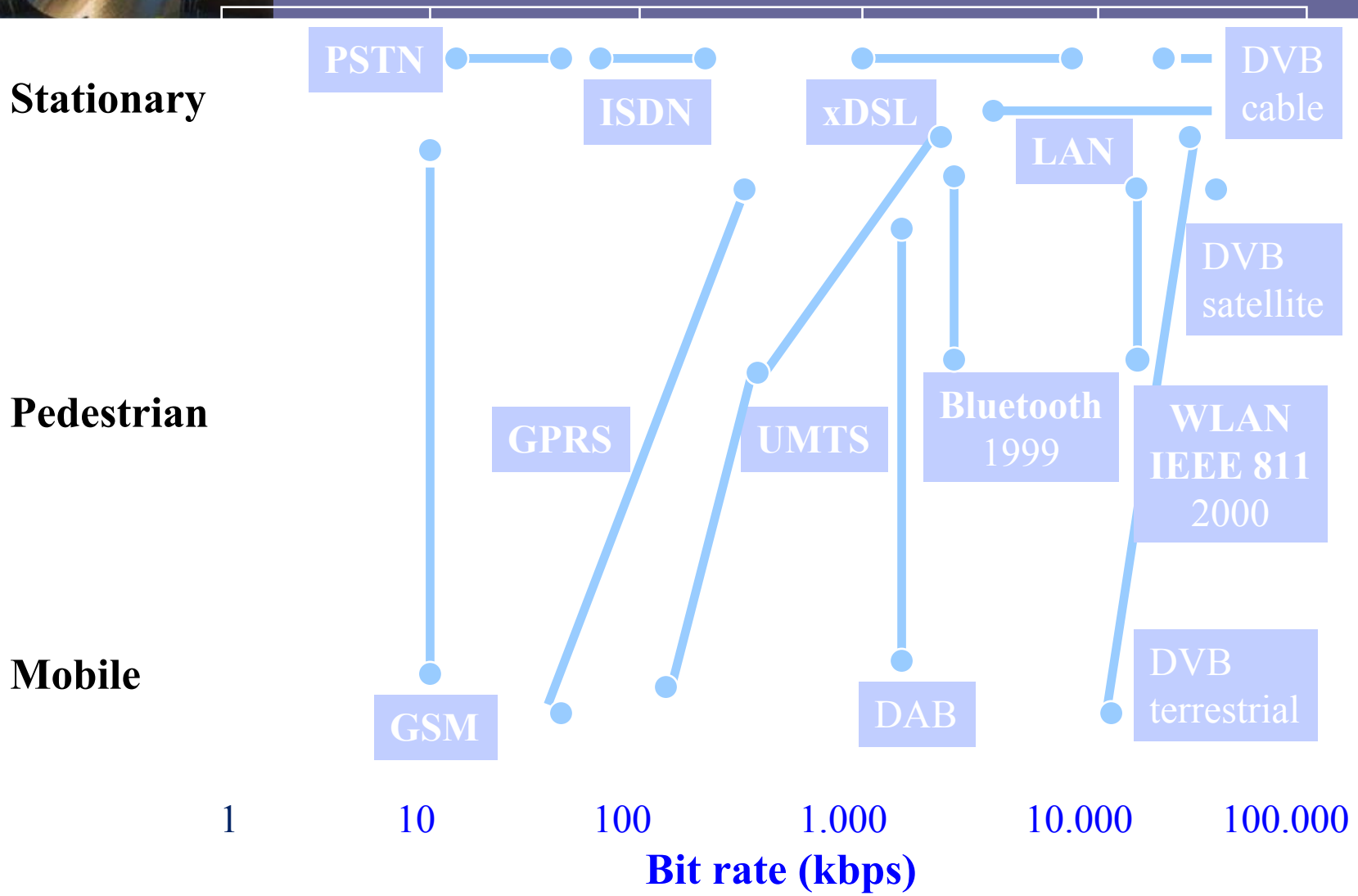
Fast Technological Change

- Covers all computing technologies
- Heterogeneous and distributed computing (March et al 2000)
  - Novel technology kernels (hardware, telecom, system software- standards)
  - Distributed system architectures (design, control, performance)
  - Heterogeneous interoperability (services, semantics, metadata, ontologies)
  - Key features: *flexibility, net-centric services,*

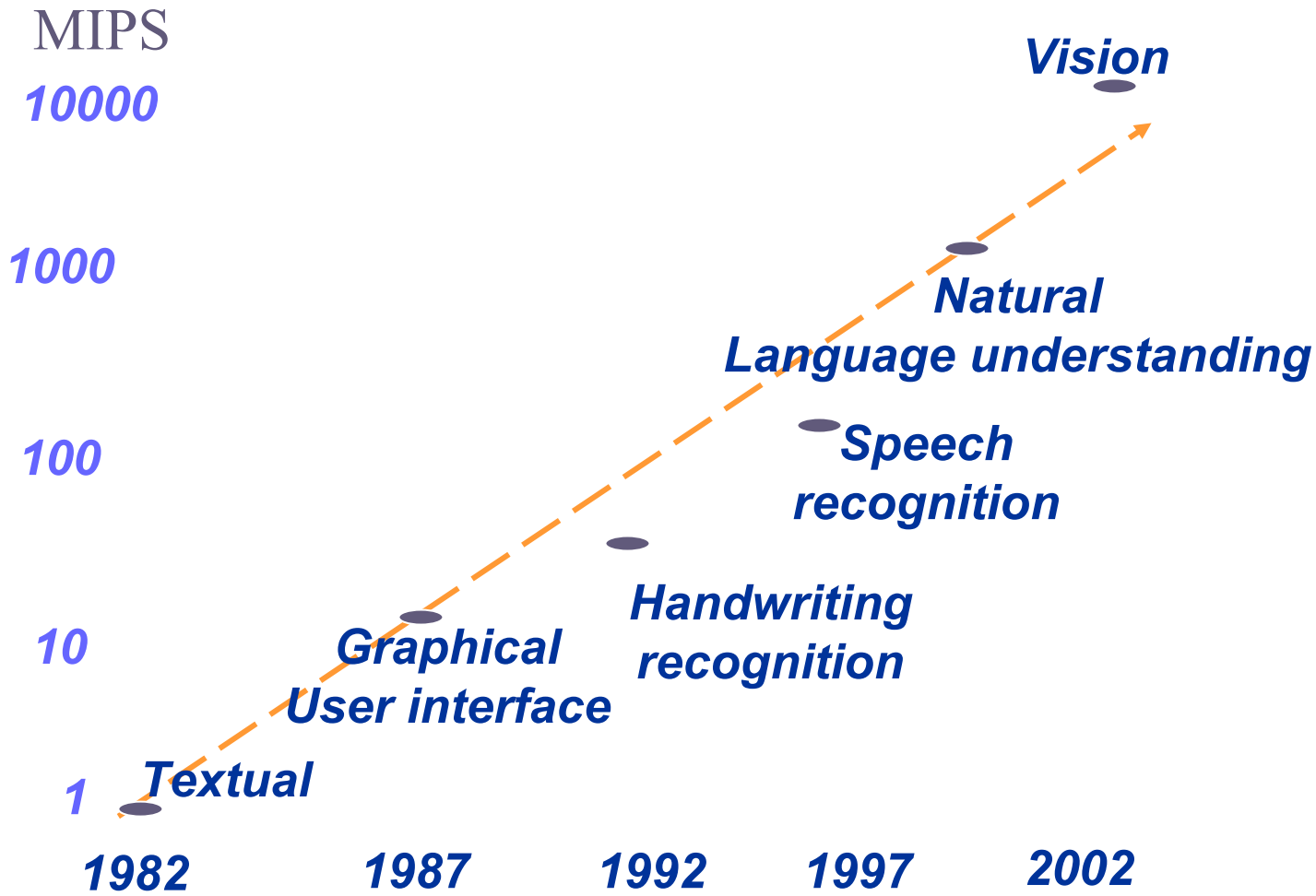
Enabling technologies

- "Semantic Web"
  - Synthesis and exploitation of content from multiple heterogeneous information sources
  - Explicit representation of semantics of data and services
- Minituarization and new intelligent devices
  - A paradigm shift in personal computing
  - LP RF networks, mesh networks, smart "dust"
- High computational power
  - Machine learning, automated planning
  - Access to remote and local information and resources

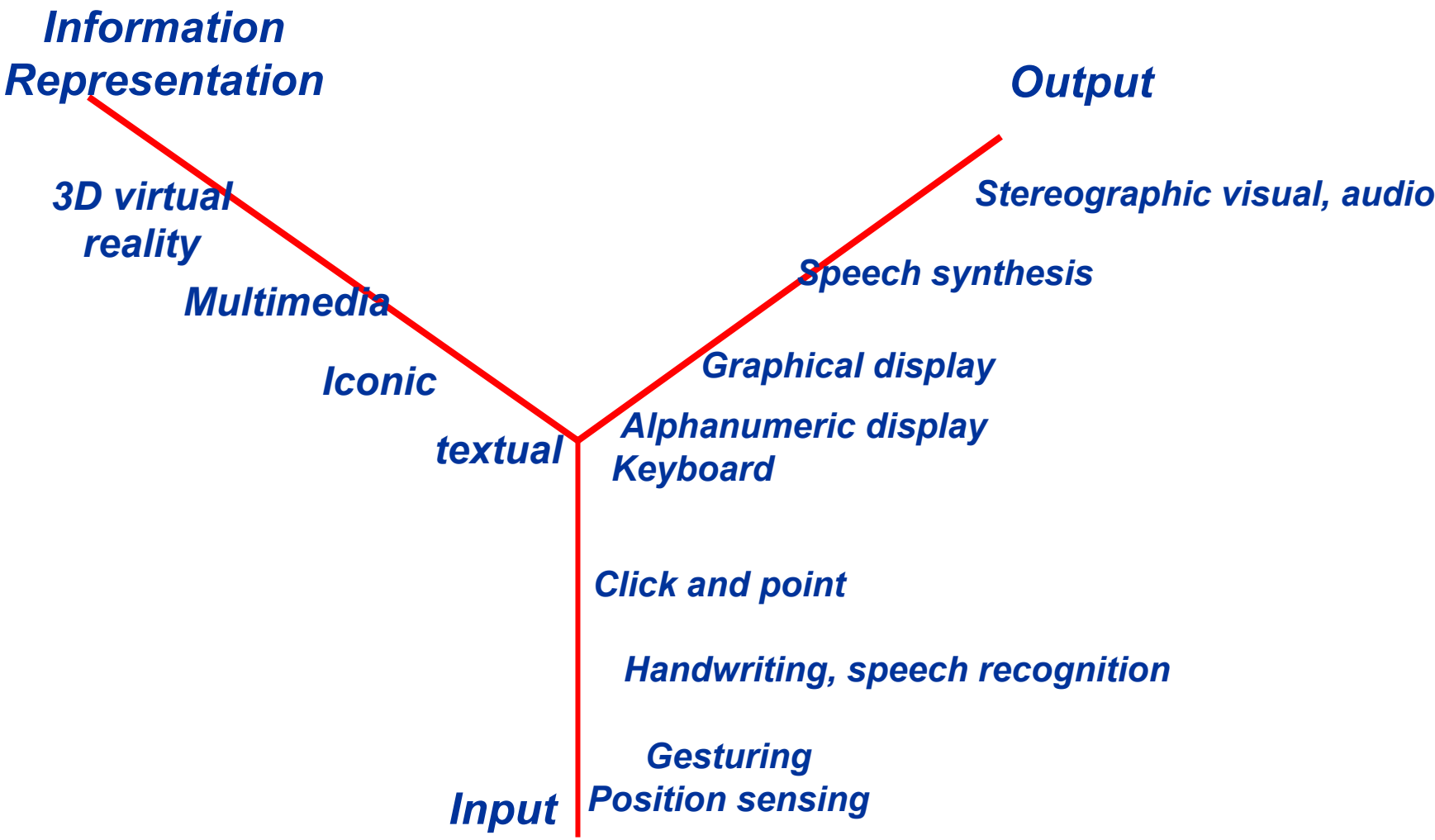
Transmission speeds



New forms of interactions



New interactions



Will we have a Universal Device?

An Environment in Change

- Today: Separate Vertical Industries

Telephony
- Wide Area Networks
- Local Network
- CPE

Wireless
- Global
- National
- Distribution Channels

Computers
- Software Providers
- Hardware Providers
- Networking
- Distribution Channels
- Hardware and Software Packages

Content
- Authors
- Musicians
- Reporters
- Distribution Channels
- Books
- CDs
- Newspapers

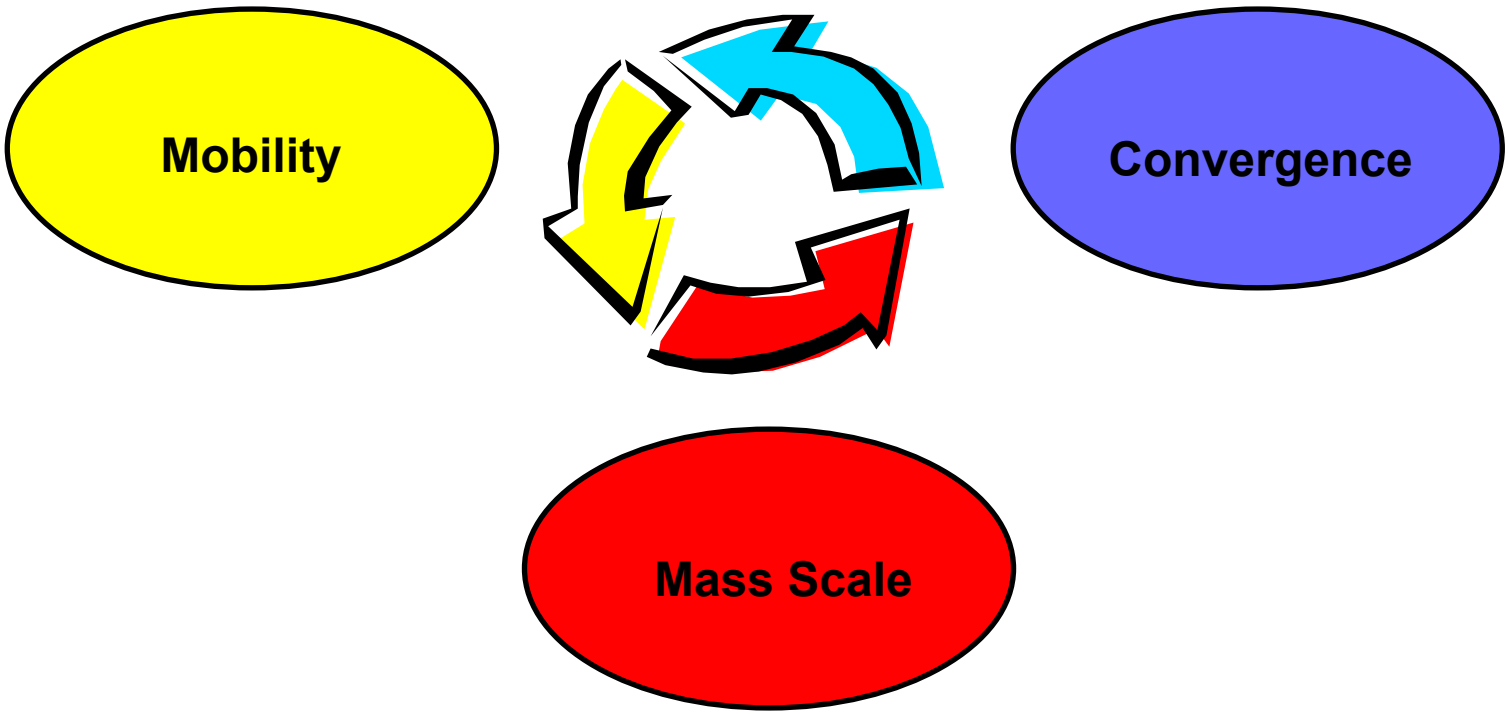
- Future: Information Industry

- Information Content
- Service Managers
- Service Networks
- Digital Services

Service Providers
- Intense Competition
- New Opportunities

Technology Convergence Is Breaking Down Barriers Between Historically Separate Industry Segments

Three Key Forces

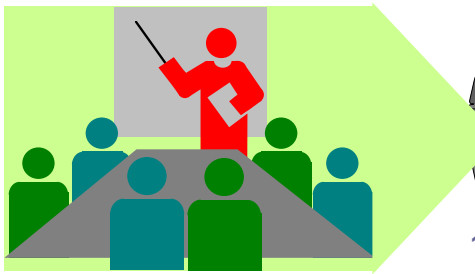


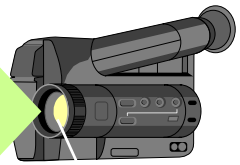
Digital convergence

- Digital convergence: enabled by computing costs and chip design + open standards
  - New forms of engagement with digital services
  - New services (entertainment, telematics)
  - Integration of services (video+ data)
- Challenges
  - **Interoperability** and **peer-to-peer synchronization** becomes critical
  - Requires **social ontology** to support social mobility and semantic interoperability

Digital Convergence

The conversion, processing, movement of all media in binary





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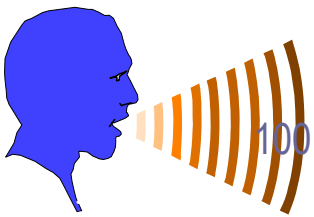

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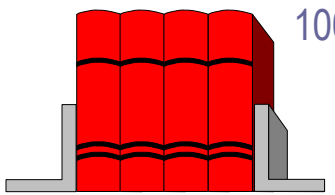

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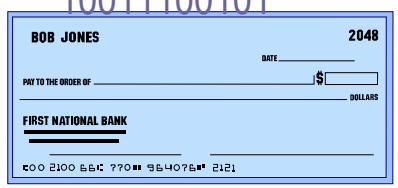
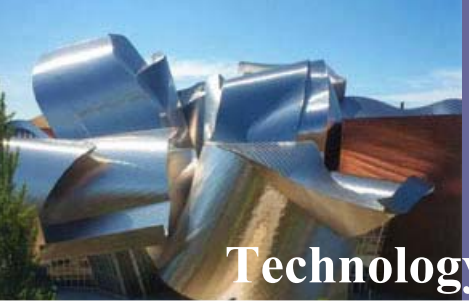




The New Digital Environment

Technology

Market

Information Infrastructure

Connectivity and service availability via an open network

Digital Convergence

Transformation of physical media into digital format

Computing Power

Doubling of digital engine capacity every 18 months

Open Standards

For transmission, presentation, interaction, security

5 A Service

Any service any time, any place, any device, any user

Mass Customization

Tailoring of product/service to unique needs of the customer

Computer Literacy

High penetration of computers and knowledge to use them

Information Industries

Value increasingly derived from information content

Digital Service Characteristics

- Migration of applications, telecommunications and media to information rich environments
- Enable new business models and service channels and capability (c.f. Kazaa, Google, E-bay)
- New forms of interaction, environments accommodating the user
- Wireless “smart” devices in the home, car, and pocket
- Device location and context awareness matters

Mobility

- Mobility covers physical mobility and social mobility
  - Social: roles, capabilities, rights, preferences
  - Physical: **micro mobility, local mobility, remote mobility**
  - Technical: **mobility of services** across platforms
- Enables new services as combinations of social, service and physical mobility and independence between services and locations
- Demands: digital convergence (micro, remote), creates mass scale (occasions of use, types of use, pervasiveness) services

Mobility makes things different

- Device location and movement is a completely new dimension
- Devices are different with different mobility features
- Usage contexts and needs are different
  - Independence between the content and the medium (Ex: CNN service)
  - Miniaturization of devices

Dilemma:

The internet represents a departure from physical reality **but** mobility grounds services and users more to the physical world

Mass Scale

- Mass scale: services provided in principle at a global level, pervasiveness implies high volumes
  - Internet capable mobile devices: 1 billion by 2003
  - 300 million Bluetooth devices in US alone by 2003
- Challenges: scalability, reliability, complexity, security and performance
- These are affected by both mobility (coverage, network features) and digital convergence (bandwidth, QoS)

Mass scale

- The amount and diversity of computing devices connected and used, volume of information transfer and connections grows in exponential scale
- Enables new services, organizational capabilities and business models (service economies)

Examples of new services

- Wearable applications
- New Service models
- Intelligent local environments

Wearable applications

- Tasks which are information intensive and demand unobstructed movement and reach
- Complex maintenance tasks (switches, airplanes, power-stations)
- Wearable computers for maintenance
  - audio contact for engineers
  - Upload technical manuals for items operated
  - Provide “organizational memory” for related tasks

New service applications

- GM service “Onstar”
- Progressive Auto-insurance “Autograph”

GM ONSTAR Initiative

ONSTAR'S PERFORMANCE OVER TIME

	• 1999	• 2000	• 2001
Customer base	***44000*** 4,000	100,000	2,000,000
Availability in models	• Two Cadillac models		• 36 GM models as standard/optional factory equipment – Lexus – Acura – Audi – Subaru & Isuzu
Churn rate	• 70%		– 50-60% (GM sources) – 20-30% (market sources)
Key initiatives	– Started introducing Onstar as optional/ standard equipment in several GM models – Started free service for 1 year	– Introduced "Batman" ad and achieved high customer awareness(e.g 90% customer awareness of "Batman" advertisement)	– Introduced Personal Calling and Virtual Advisor services – Holds 80% of all telematics customers in U.S.A

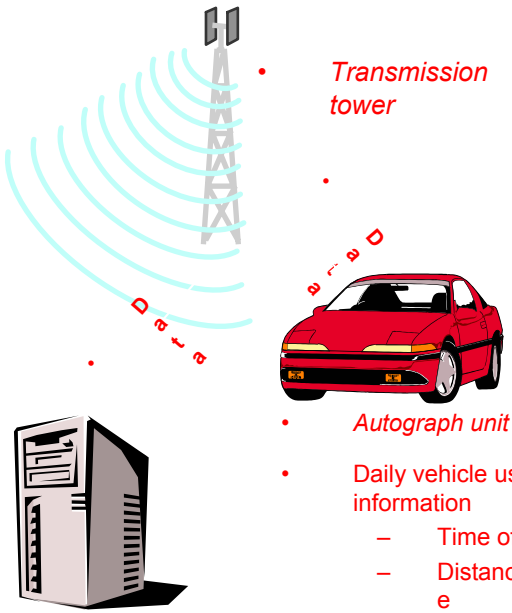
Source: Automotive News, March 4, 2002

Progressive "Autograph"

With Autograph™, insurance bills are calculated monthly based on actual vehicle usage data

HOW IT WORKS

•1. Monthly upload of vehicle data by mobile communications



- *Transmission tower*
- *Autograph unit*
- Daily vehicle usage information
  - Time of day
  - Distance/time
  - Locations driven
- *Data receiver*

•2. Data converted into a monthly premium based on travel zones and time of day

Time of day	Zone 1	Zone 2	Zone 3
Morning	300m	100m	400m
Afternoon	$120	$5	$20
Evening	20m	00m	200m $10
Late night	$8	$5	60m $6
		Total	$74

- Maps defining zones are given to customers

•3. Customer billed for usage in past month

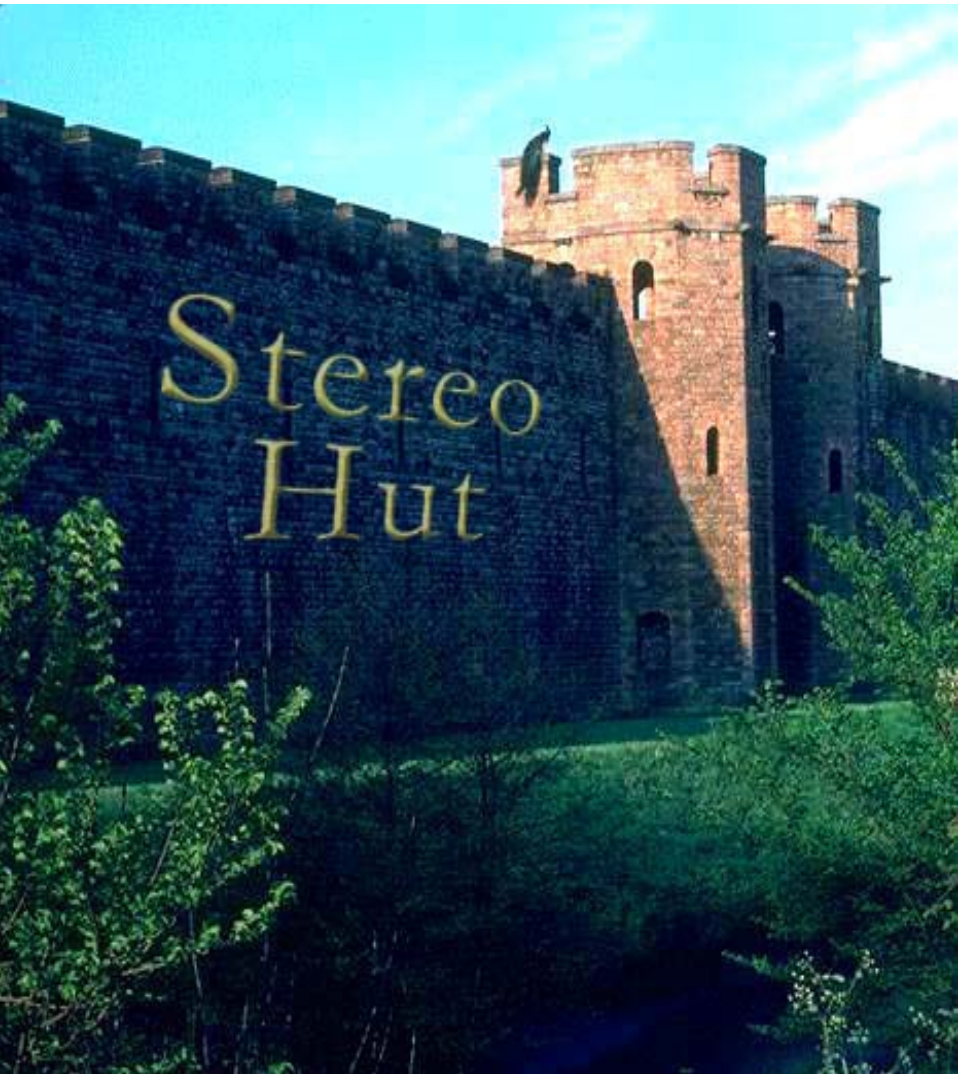
- In this case, $74, a savings
- of **22%** from a standard policy

Source: Progressive

Intelligent environments

- Environments that embed sensors and enable intelligent adaptation to the computer, user or resource
- Contextual sensing, adaptation, resource discovery and augmentation
- Examples
  - Intelligent shopping assistants (what is available)
  - Intelligent medical cabins and immediate services
  - Intelligent context aware environments (available resources, who is where, how can I do X, where can I find y)

Your Store is Not Your Fortress Anymore



Mobile Services eliminate physical boundaries.

Stores can no longer use their presence to monopolize the services available to you.

home

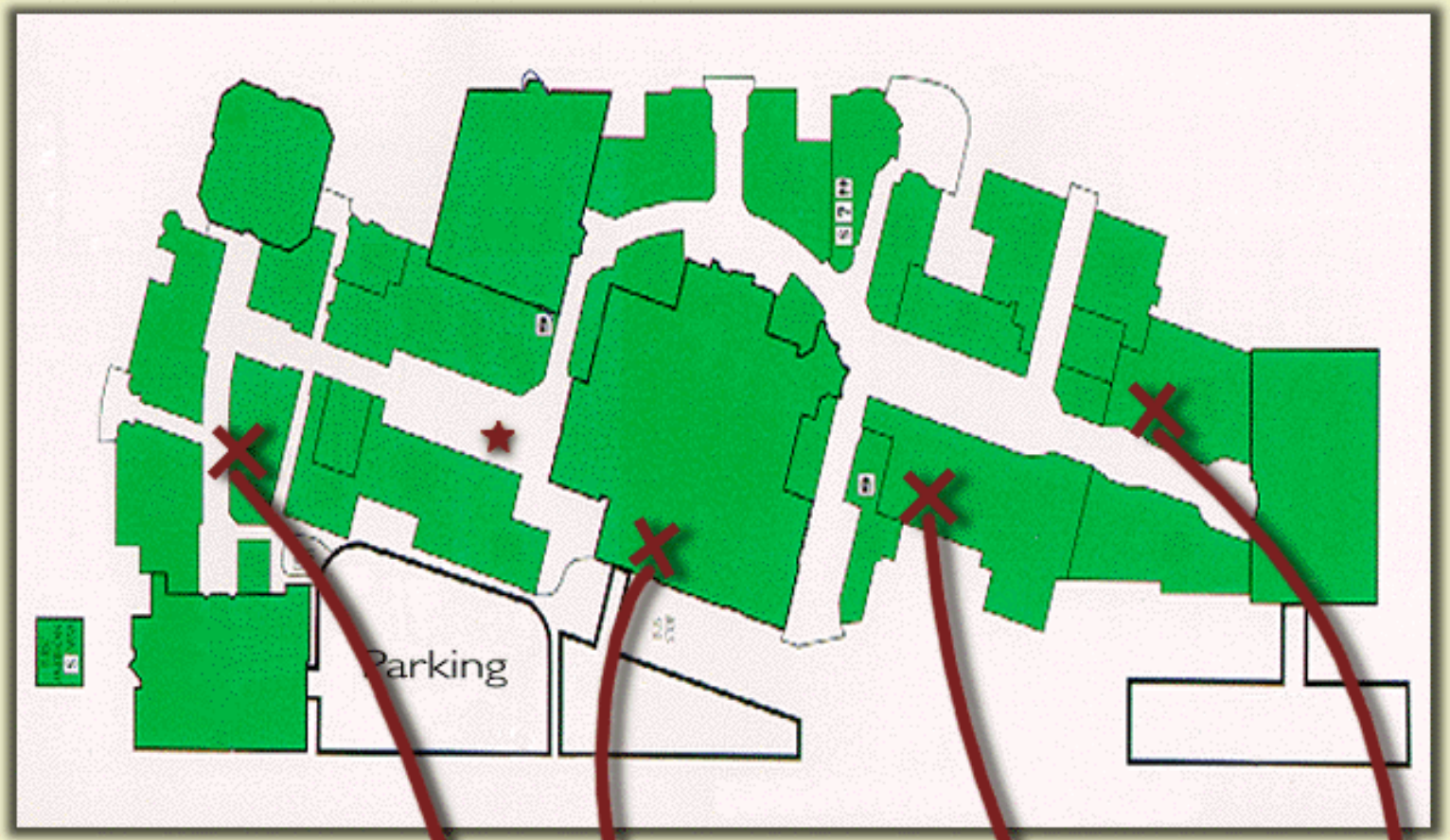
list

shop

fun

help

shopper's eye



Mobile Valet:
Who do you want to help you?

Research Challenges

- Ubiquitous computing challenges our assumptions in computing about time and space
- Require equal attention to *social* and *technical* problems and the *interplay* between them
- Require equal attention to *different levels of analysis* and the *interaction* across them

IS research issues for digital services

	Individual level	Team level	Organizational level	Inter-organizational level
Services				
Design	▪ evelopment of personal, intelligent, mobile assistants ▪ icro-mobility ▪ ontent and medium ndependence	▪ Socio-technical transactive memory ▪ Coordination of data and knowledge creation through technical "scripts"	▪ nterprise applications and architectures ▪ New workflow and organizational structure ▪ ocial ontology models	▪ nter-organizational agents ▪ ransaction and coordination mechanisms
Use and adoption	▪ se of information channel ▪ ense-making and enacting in virtual environments ▪ anagement of personal information	▪ eam level adoption and configuration of services ▪ eam process design and management – leadership, decision-making, communications	▪ Organization wide use and adoption of services Service management and governance 3	▪ ndustry adoption and network externalities ▪ Emergence, coordination, and control of standards and services
Impact	▪ fficiency and effectiveness of decision-making ▪ nformation overload ▪ earning	▪ eam performance (efficiency and effectiveness) ▪ eam development (trust and learning)	▪ rganizational performance, and competitive advantage ▪ rganizational learning and agility ▪ lace-less processes	▪ Emergence of new industry structures and value chains ▪ ransformation of industry structure

IS Research issues

Infrastructure				
Enabling capabilities	▪ Micro mobility ▪ Synchronization ▪ Peer-to-peer connections ▪ User profiling ▪ Intelligent environments ▪ Directory information ▪ 4	▪ Awareness support ▪ Simultaneous local and remote mobility	▪ Integration and maintenance of heterogeneous systems ▪ Partnerships in services ▪ Maintenance of geographically dispersed computing resources ▪ 3	• Standard development • Interoperability • 1
Governance and control	• Access privileges • Security • Privacy • Visibility of personal / public knowledge	• Team level ownership and control of data and information • Access and control of services	• IT services governance • Enterprise architectures • Pricing and control of IT resources • 1	• Regulatory policy and instruments • Pricing • Security and privacy • 1

Key Research Problems

- Design and deployment
  - **Standards design and diffusion** (architectural control, capabilities)
  - **Context and level of design** (infrastructure, application, user, context)
  - Criticality of **socio-technical design: time, space and productivity**
  - Co-evolution of organization and technology

Standards: Broadband Mobile Services Diffusion

- Objective
  - examining factors that explain different patterns of diffusion of broadband mobile services in six different regions
  - the US, the UK, Scandinavia, South Korea, Japan, and Germany
- Key questions
  - understand the social embedding process of large-scale complex technology
  - Understanding the varying roles of critical actors in different realms (innovation systems, the market place, and regulatory regime) and their relationships
  - Understanding the role of standards
- Research methods: Interviews and archival data

Context and level of design

- **Design for infrastructure**: architectural control, trade-offs with functional and non-functional requirements
- Infrastructure: computing, data and service capability, integration of vertical and horizontal capabilities (protocol stack)
- **Design for applications**: task focused, goal oriented, what assumptions do you make about computing capability and platform; how to make tasks expandable and adaptable?
- **Design for users**: how to manage user interface, distribution of tasks between different devices
- **Context**: design for specific context and adaptation
- Design for simplicity?

Design Challenges

- Research Challenges
  - *Adaptability* to multiple access channels (infrastructure, application, user, context)
  - Configuration and integration of services must be flexible and scalable (both from the pull and push side); WWW based portal model not adequate
  - Transaction models and solutions for huge transaction volumes of heterogeneous types
  - Scalability, reliability, complexity, usability
  - Distributed management of content and metadata management largely unresolved (despite XML)

Key Research Problems

- Time-space
  - Coordination and control: very little research how time and space relate to coordination and context, dependent vs. independent variables
  - Virtuality and physicality: the new way of organizing our life between real and virtual

Key Research Problems

- Impact
  - productivity
  - emergence of work practices and new processes

Productivity

- Setting
  - International logistics company
  - Deployment of new ubiquitous computing tools to support remote and micro mobility
- Features of the ubiquitous computing support
  - Automating
  - Coordinating
  - Controlling
  - Embedding
- Key variables
  - productivity gains within a network
  - emergence of complementary assets
- Methods: Econometric, controlled sampling + Ethnographic

Business Impact of UIE

- Automating
  - Automated processing
- Connecting
  - “Real Time” communications
  - Communications in loading dock areas
- Embedding
  - Faster response in unusual situations
- Controlling
  - Fast configuration and utilization of various local computing devices

The Future of UIE

- Automating
  - Wearables
- Connecting
  - Totally “unobtrusive” communications environment
  - Data, Voice, Video
- Embedding
  - Integrated in Customer Business Model
- Controlling
  - Voice activation

Work practices

- Setting
  - An urban university hospital emergency room with test lab
  - Highly mobile (local and micro), time-critical, high-velocity, inter-dependent tasks
- Key features of the study
  - Studying mobility of actors and artifacts along with processes associated with current practices
  - Envision new technological capabilities that can address mobility and information/coordination problems
- Key variables
  - Error rates, coordination with and across teams, changes in work practices and routines
- Methods
  - Ethnographic study combined with statistical data on productivity and error rates

Research Challenges with New Mobile Services

- SERVICE CONCEPTS AND STRATEGIES
  - *All* information services may need careful rethinking and can be transformed
  - Design, management and packaging of digital services based on new innovative business models (c.f. Autograph)
  - Understanding user *needs* in a new information rich environment is difficult (contrary to expectation people liked Autograph)
  - Evolution and expansion of services based on *user learning; continued design*
  - *Many* services based are *community based*

Research strategies

- New and novel design issues
  - Analysis and investigation of REALLY LARGE SYSTEMS (infrastructure)
  - Policy issues more prominent (privacy, surveillance, security) but they are becoming *technical*
  - Analysis of processes as they unfold at up-close relationship (not just tasks or HCI issues); demand for sensitive data
  - Spanning the global / local dialectics

Research challenges

- Study environments rather than applications; configurations of services which are contextualized
- New borders between social and technical; how to analyze shifting boundaries with our research instruments

Concluding Thoughts

- Promising area for large scale socio-technical research
  - Requires multiple research methods
    - Design, quantitative and qualitative studies
  - Requires refinements and developments of research methods
    - Simultaneous engagement of multiple layers of data collection (a tension between global and local)
  - Requires new types of theorizing
    - Time-space and coordination
    - Interaction between virtuality and bodily experiences

Questions?