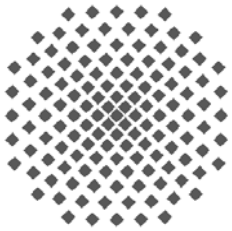


University of Stuttgart

Institute of Parallel and
Distributed Systems (IPVS)

Universitätsstraße 38
D-70569 Stuttgart

Context-Awareness: What If Computers Know the World?

Kurt Rothermel

Institute of Parallel and Distributed Systems (IPVS)

Universität Stuttgart

Technology Trends

Components are getting smaller and cheaper

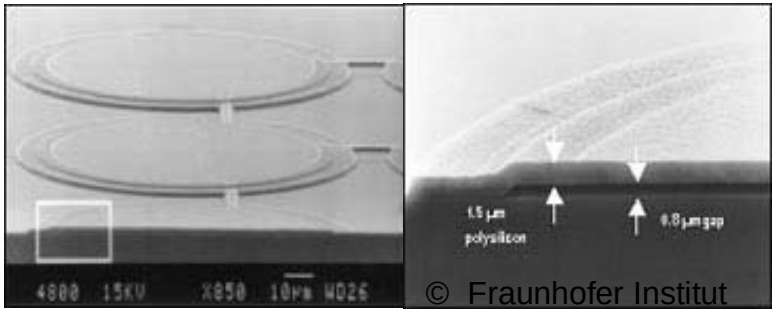
- Computers, sensors, communications

They become integrated

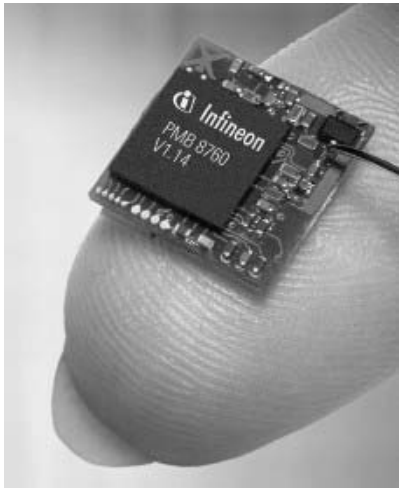
- Mobile devices, „smart things“, …

They become networked

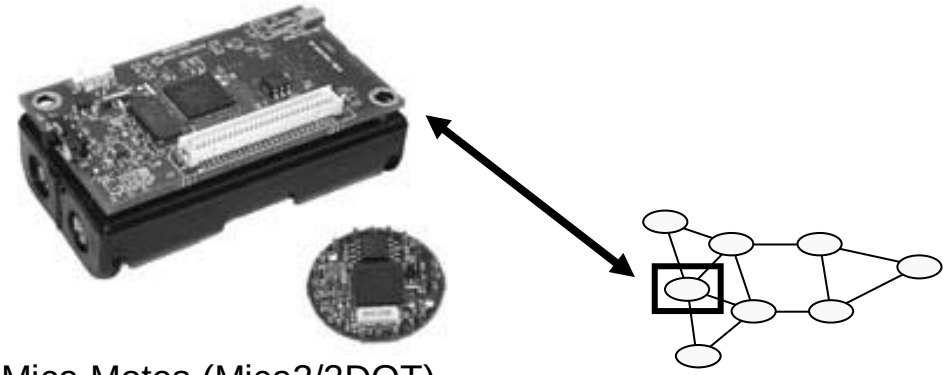
- „Smart spaces“, sensor networks, …



Pressure sensor: ∅ membrane: 120 µm



infineon’s Bluetooth-chip



Mica Motes (Mica2/2DOT)
(Crossbow Inc.)

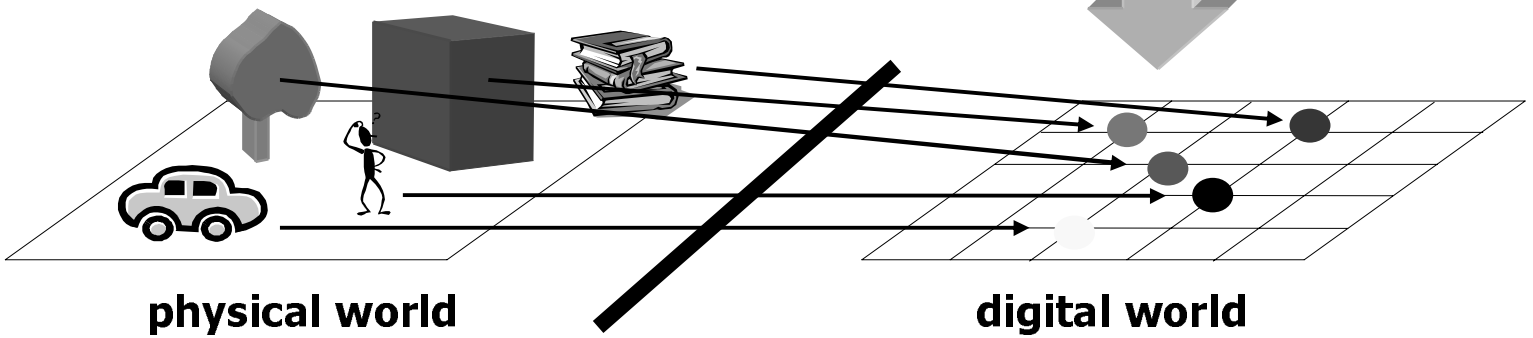
Source: UC Berkeley

Technology Trends: Linking Real and Digital World

Technology trends
- Miniaturization
- Price decline
- Integration: smart things, sensor networks

→ Proliferation of sensor systems

Context-aware systems
- Position, direction, velocity
- Objects in vicinity
- Temperature, ...



Outline

Technology Trends

Context-aware Applications

World Models

Context-aware Communication

Conclusions

Context-based Applications

Context is any information that can be used to characterize the situation of a person, place, or object

Context-aware applications include

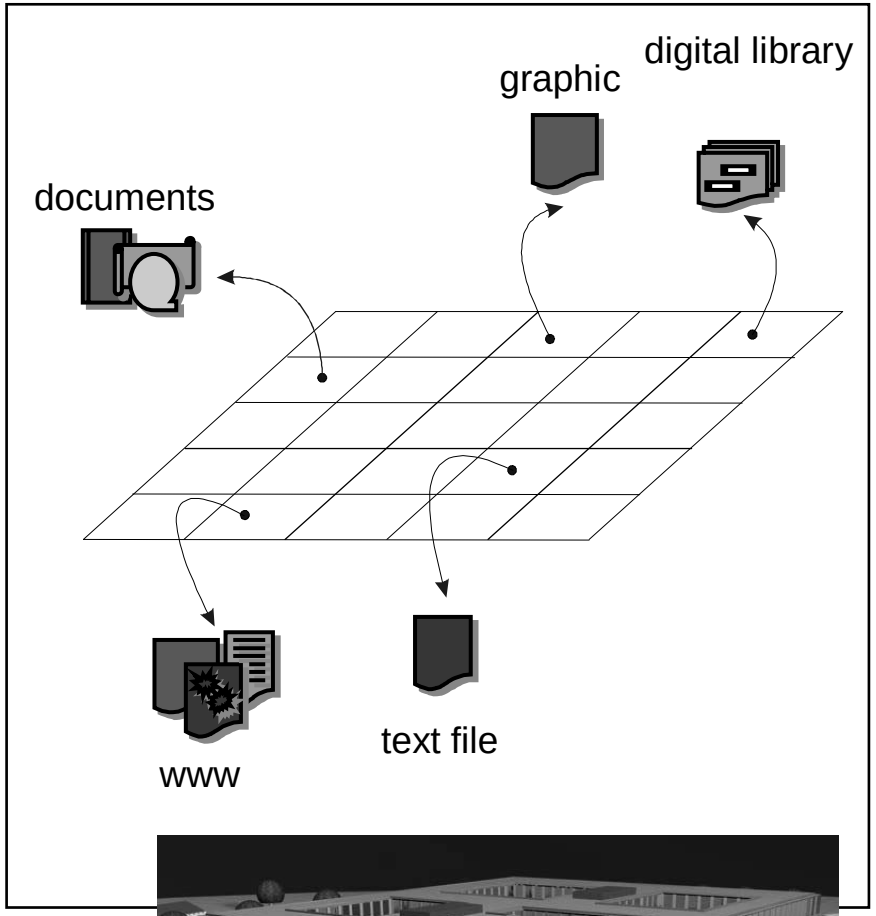
- Context-based Selection: Where is the next free taxi?
- Context-based Presentation: Switch to speech output if I am driving faster than 100 km/h!
- Context-based Action: Tell me if my manager enters the building!

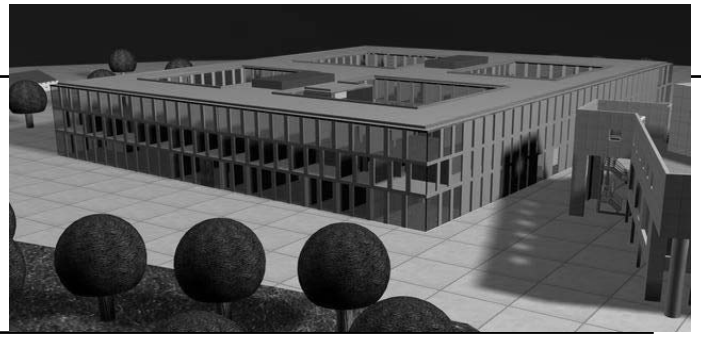
Most applications will be context-aware!

Applications: Location-Based Services

Linking physical objects to information/services

- Physical objects serve as anchor points to information/ services
- Spatial access to information/services
- Models: Maps, 2.5D, 3D static and mobile objects, objects with dynamic state





Application: Ubiquitous Computing

Disappearing Computer

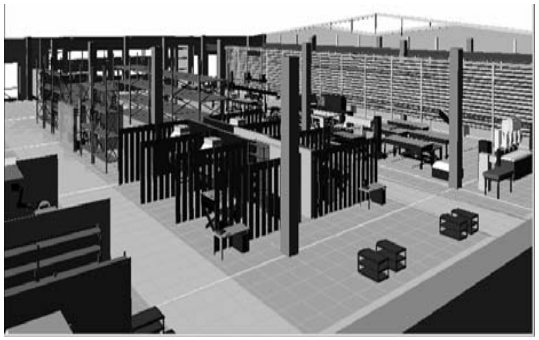
Interaction with the computer beyond the desktop metaphor

- users interact with their physical environment

Metro AG

Smart Spaces

- Cars (cell-phone integration)
- Meeting Rooms
- Aware Home
- Smart Factory
- Future Store
- …



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Georgia Institute of Technology

Outline

Technology Trends

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Models of the Physical World

Interpretation of context based on world models

- Different models for different applications
- Models have things in common, complement each other
  geographic scope, aspects, level of detail, …

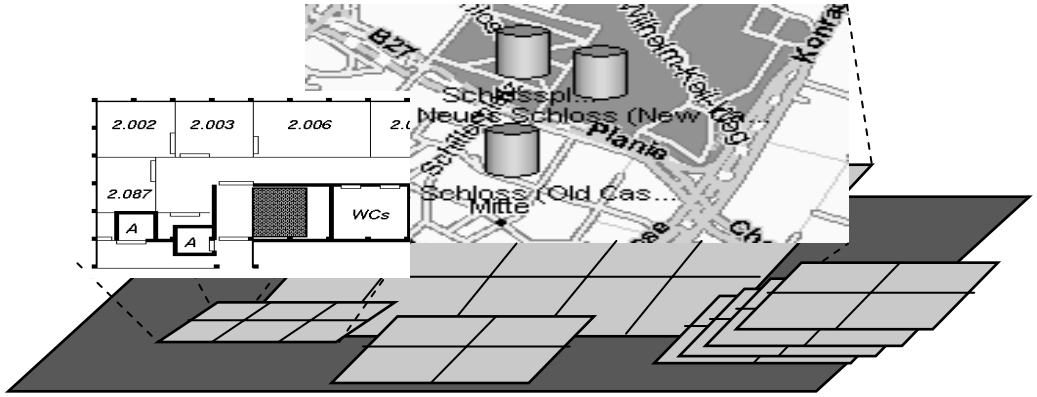
High cost for generating and maintaining world models

→ Model integration

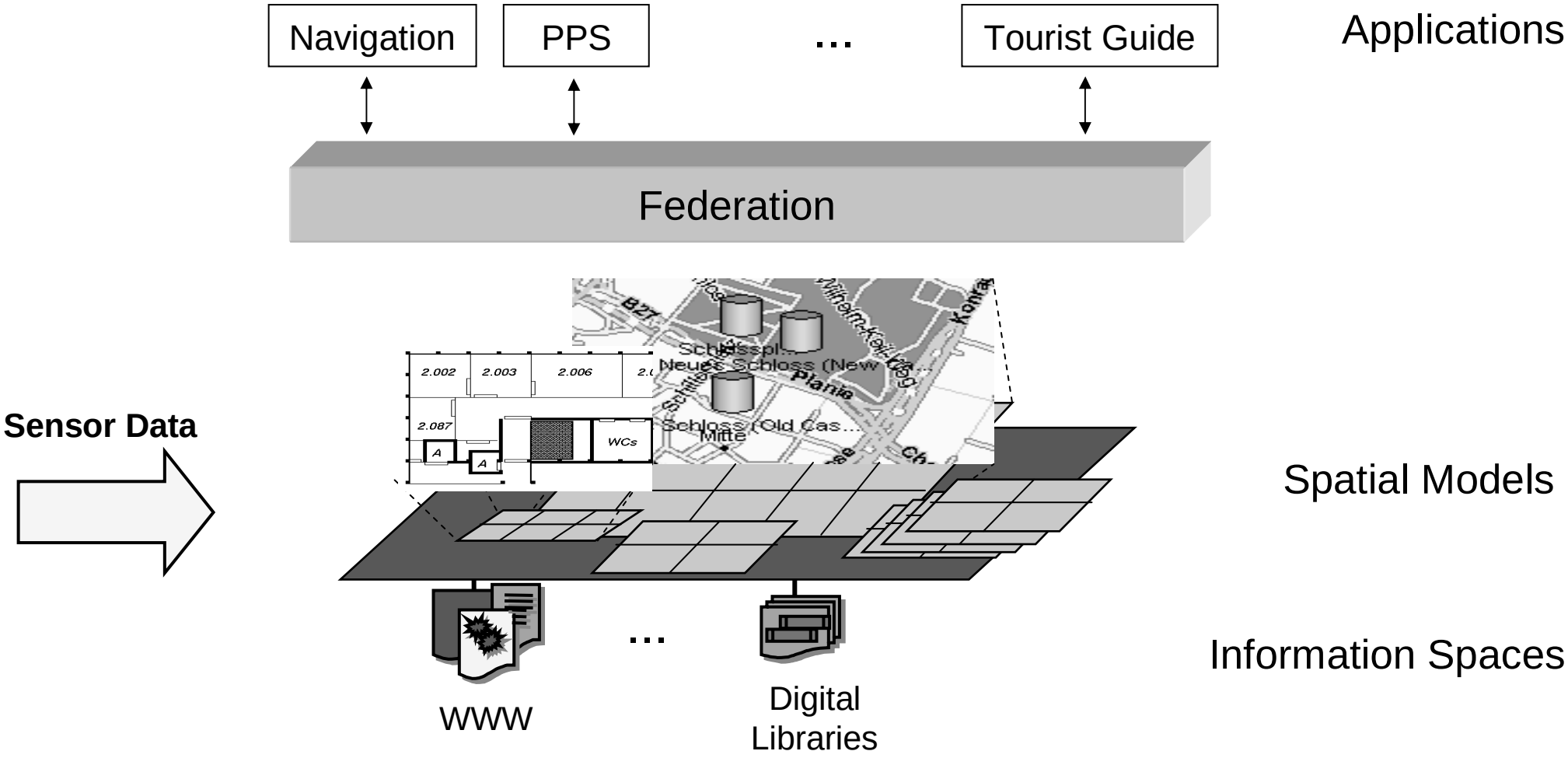
→ Model sharing

Data of

Billions of Sensors



Vision: Federated World Models



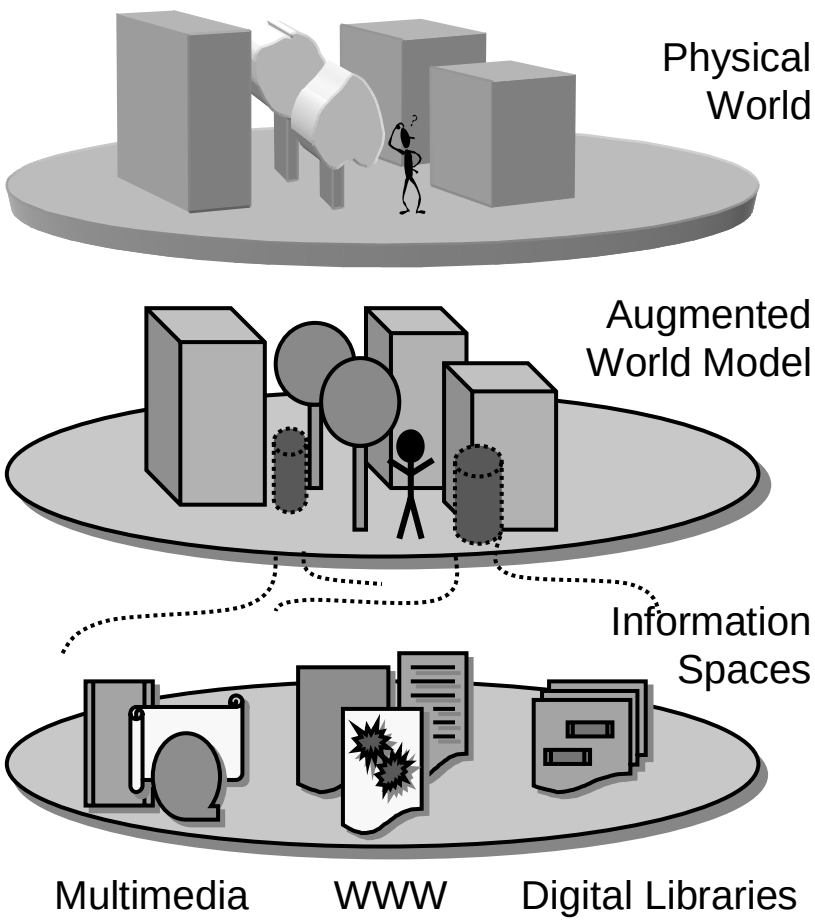
Center of Excellence "Nexus"

Goals:

- Methods to realize global world models
- Innovative context-aware
  - Applications
  - Mechanisms

Start: January 2003 at University of Stuttgart

- 30+ research staff members, 9 research groups
- First funding period: 4 years



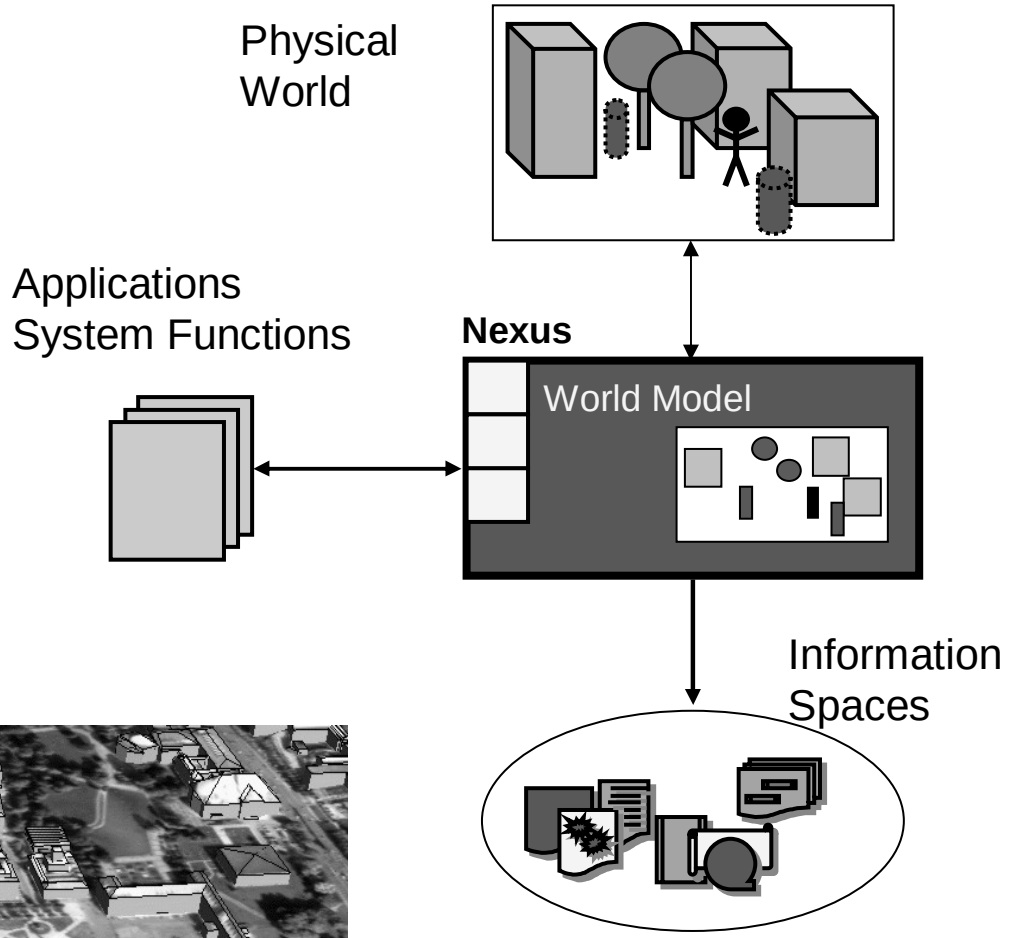
Nexus-Platform - connects physical and digital world

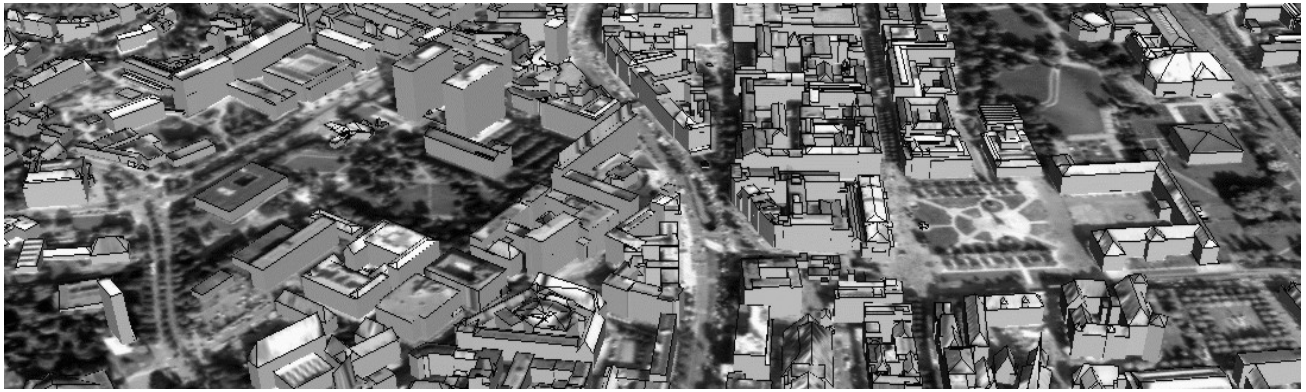
Federated World Models

- Sensor integration, consistency
- Information anchor points
- Temporal concepts

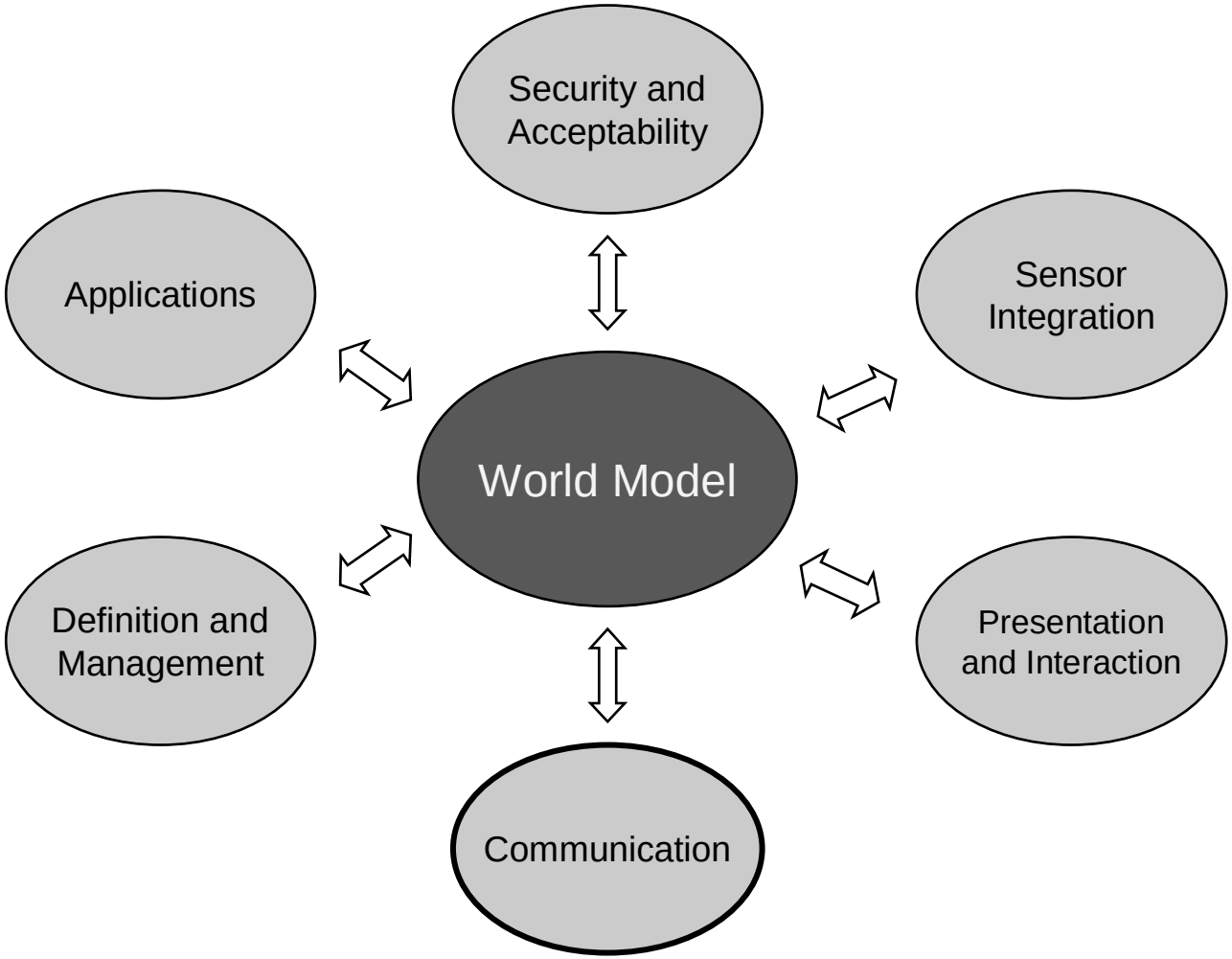
Model Interaction

- Synchronous: spatial queries
- Asynchronous: spatial predicates
- Visualization





Nexus – Research Areas



Outline

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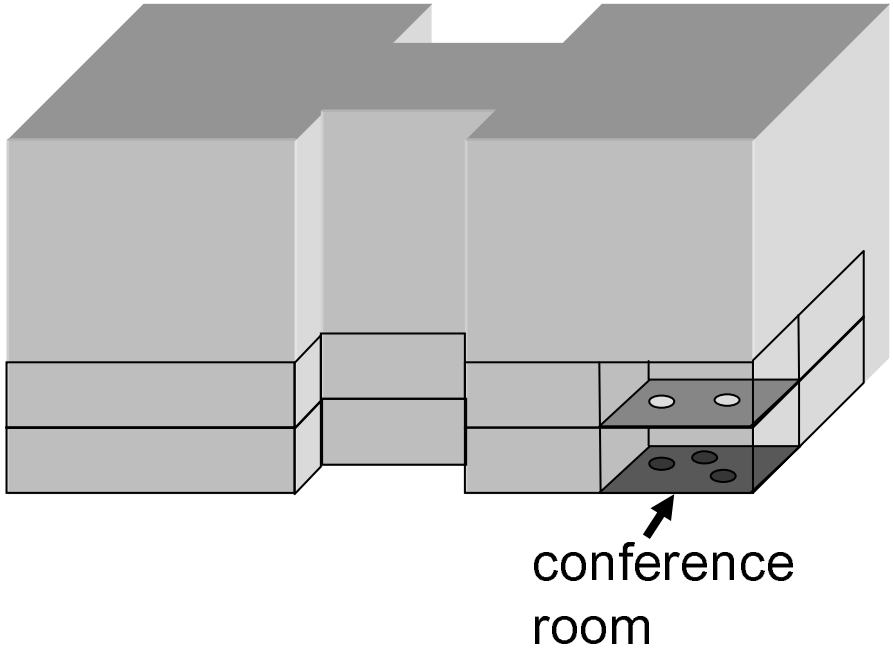
Context-aware Communication: Contextcast

Geocast: Send message to all hosts in geographic target area

- Target Areas: Streets, buildings, rooms, …
- Mobile Targets: trains, …



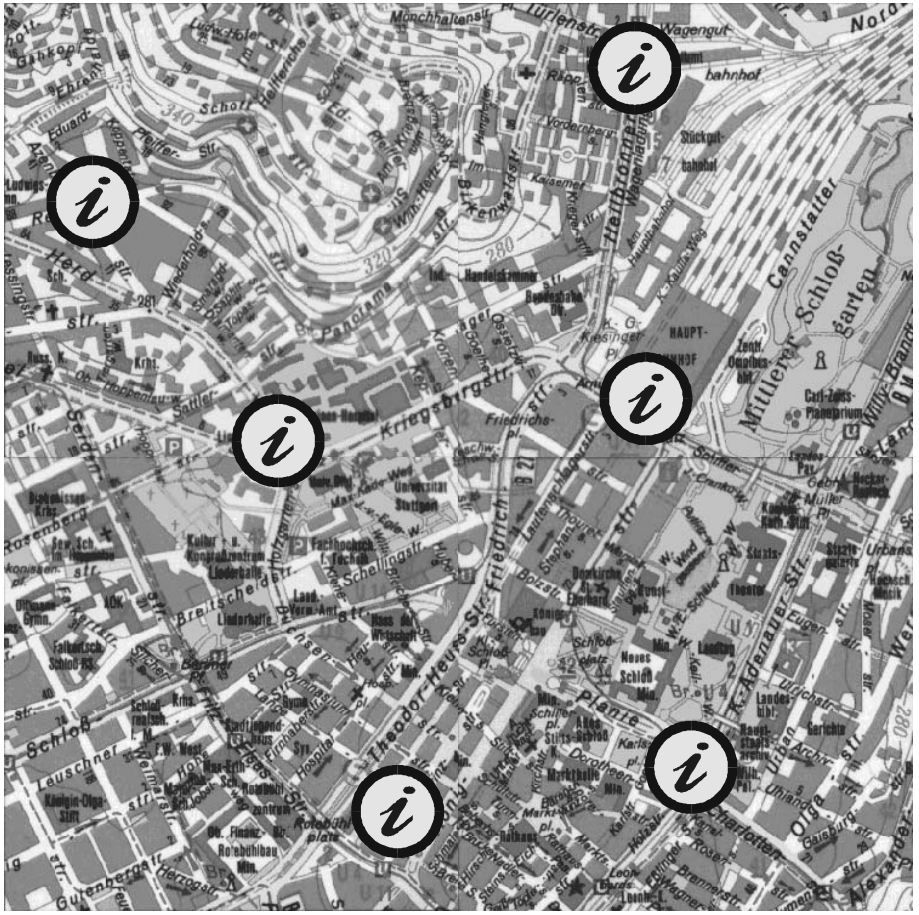
Contextcast: Send message to all persons or objects that are in a certain situation, e.g.,

- all people in town currently riding a bus
- all cars speeding on Highway 1

Context-aware Communication: Hoarding

Hotspots allow for broadband access to data (WLAN)

- 2004: 60,000 hotspots worldwide (jiwire, 2005)
- 2008: 250,000 hotspots worldwide (IDC-study, 2002)



Use of Hotspots Today

- User decides which data to download
- Typically to satisfy current information needs

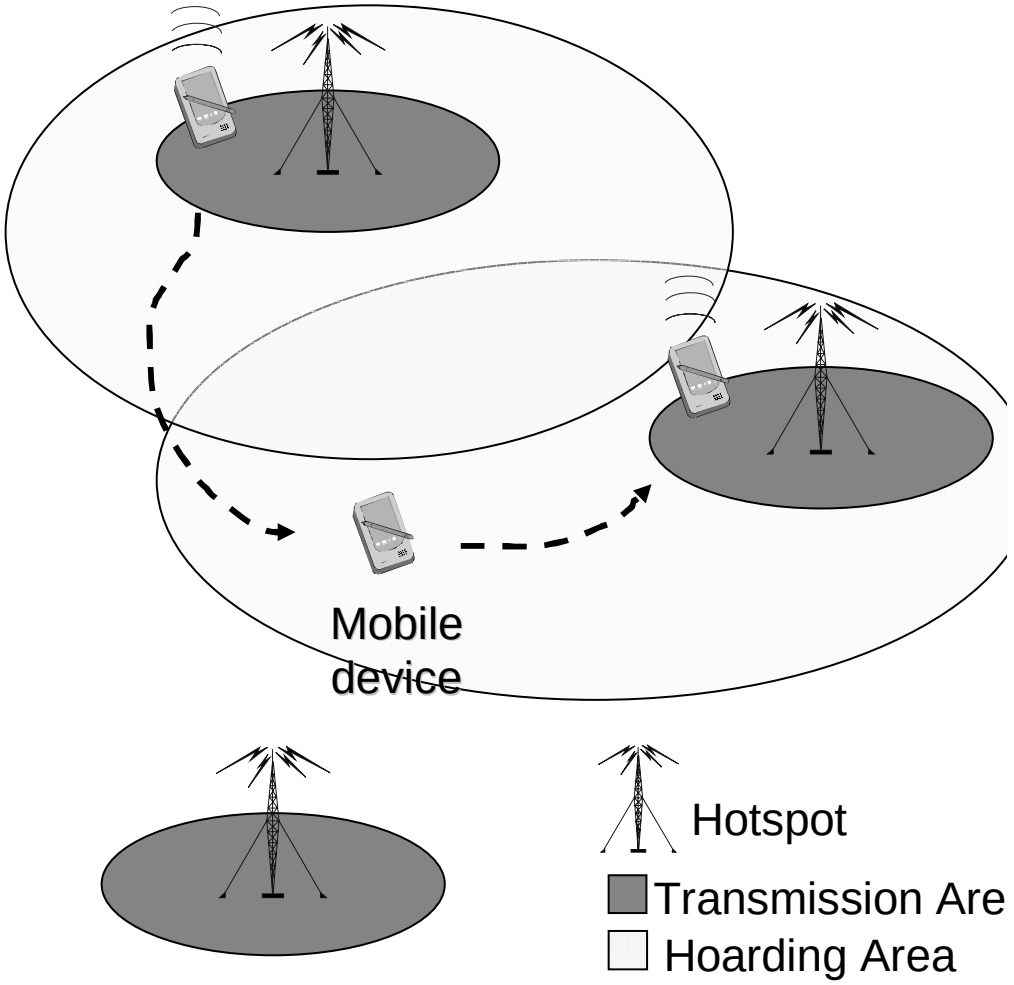
Idea: Hoarding

- predict which data a user might need in future, while not at hotspot
- automatically download those data

Hoarding: Approach

Approach:

- While in transmission area: hoard information items that might be requested in hoarding area
- While outside transmission area: accesses are satisfied from hoard cache if possible

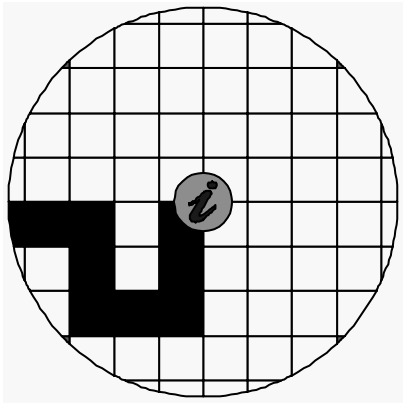


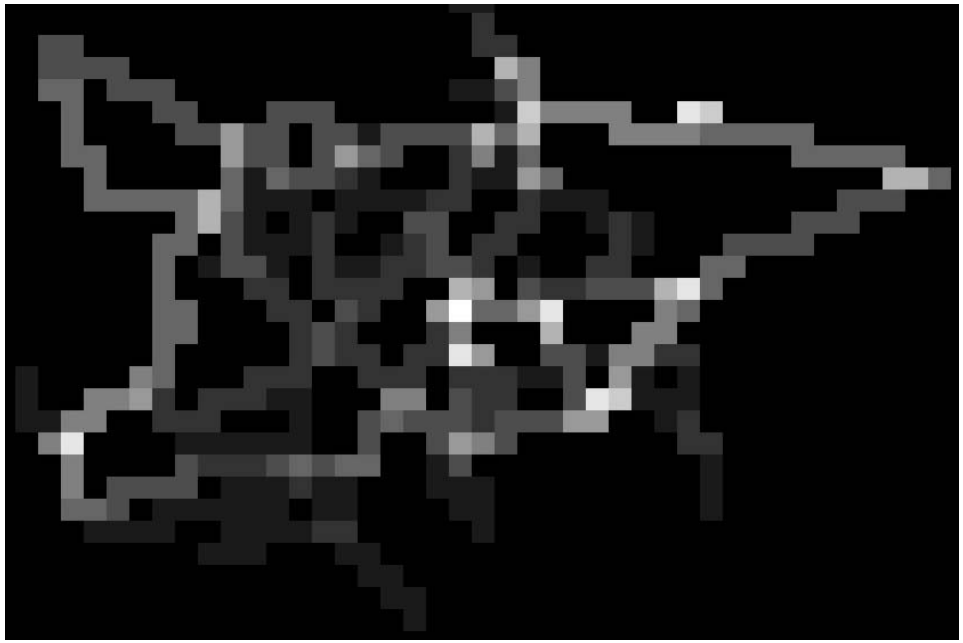
Major Problem: limited buffer and time

- Hoarding decision: Selection of data items to be downloaded
- Assumption: Data a user accesses is correlated with his location (location dependent data)

Hoarding Decision: Exploit Location Information

Hoarding Area





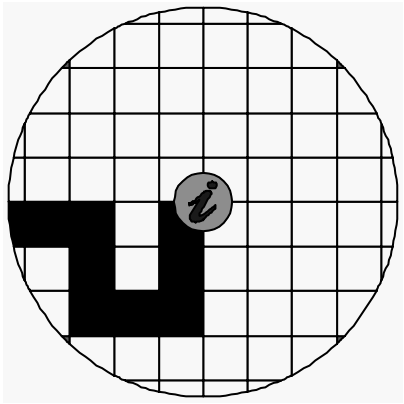
Principle: [ACM MobiCom 2001]

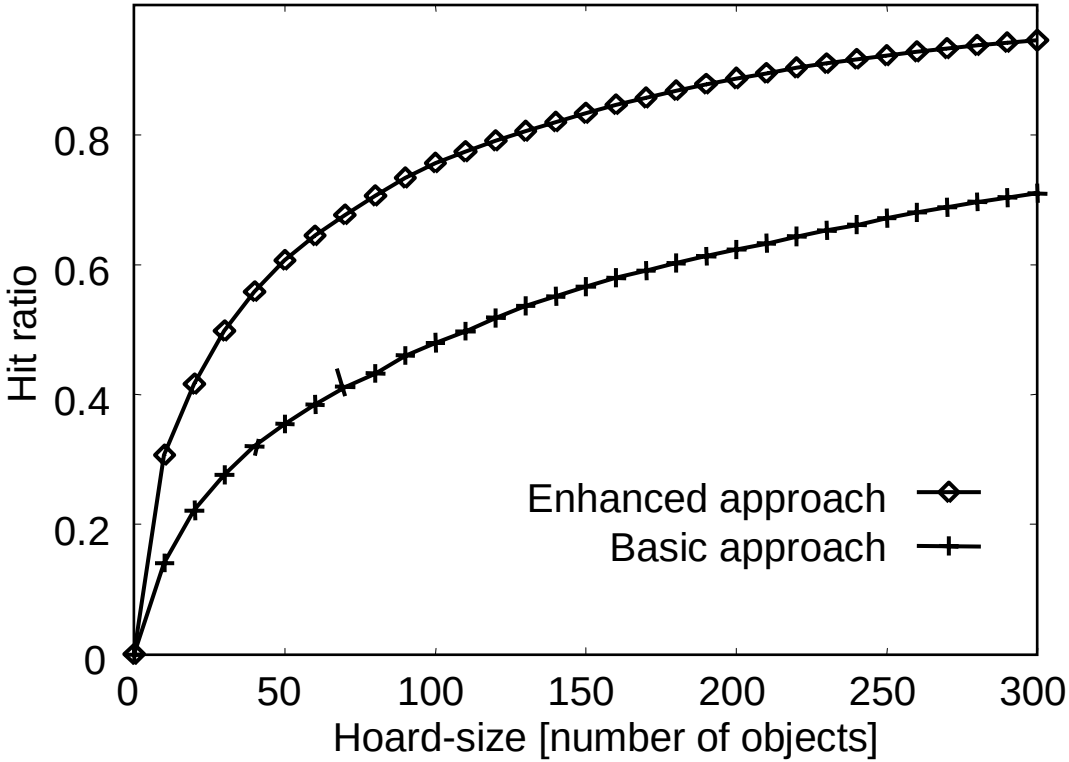
- Hoarding area divided into zones
- Mobile devices
  - record access to information items (Id, Location)
  - upload log to infostation
- Infostation computes
  - v(z): visit probability
  - a(i,z): access probability
- Hoarding decision:
  items ranked by their access probability

$$p(i) = 1 - \prod_{z \in Z} (1 - v(z) \cdot a(i,z))$$

Hoarding Decision: Exploit Location Information

Hoarding Area





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Hoarding: Context Beyond Location

User preferences

- Access behavior depends on user's interest (sports, culture, ...)
- Approach: record access behavior for individual user profiles

Semantic distance of information objects

- Hoard objects that "belong" together
- Approach for semi-structured data (WWW) based on graph analysis [MDM 2004]
  - monitor how users navigate the Web
  - further improvements in hit ratio ~ 25%

Others ...

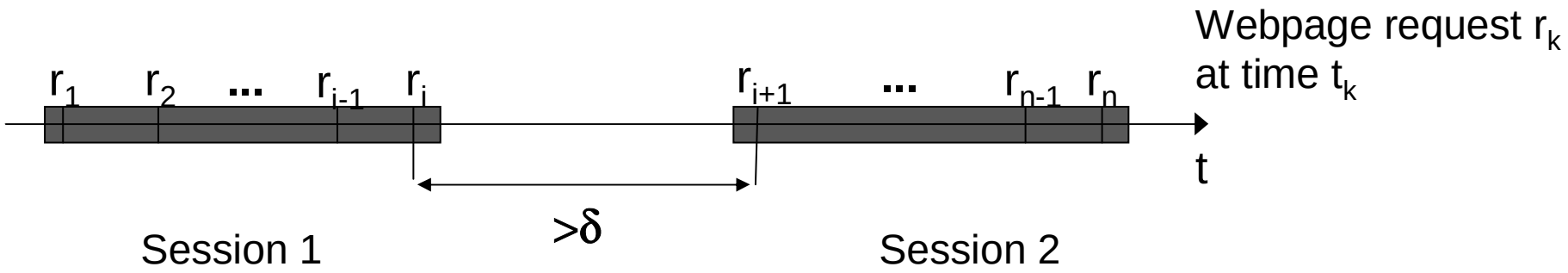
Hoarding: Semantic Distance

Derive semantic distance from users' browsing behavior

- Interpretation of uploaded user log files
- Log file: sequence of web page accesses plus visit times

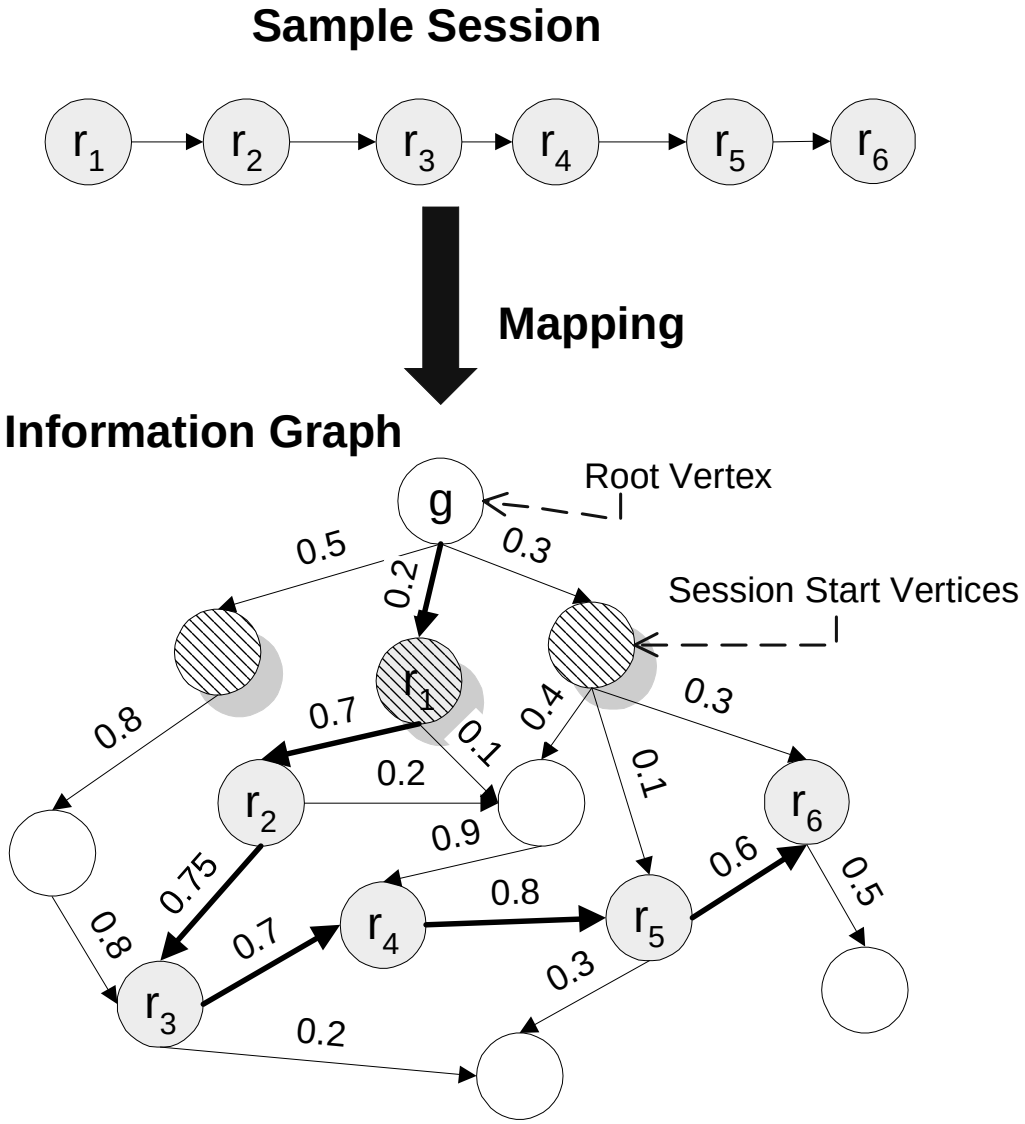
Logs are subdivided into sessions (logically related web pages)

- Based on visit periods
- Criteria: visit period > threshold δ then create new session

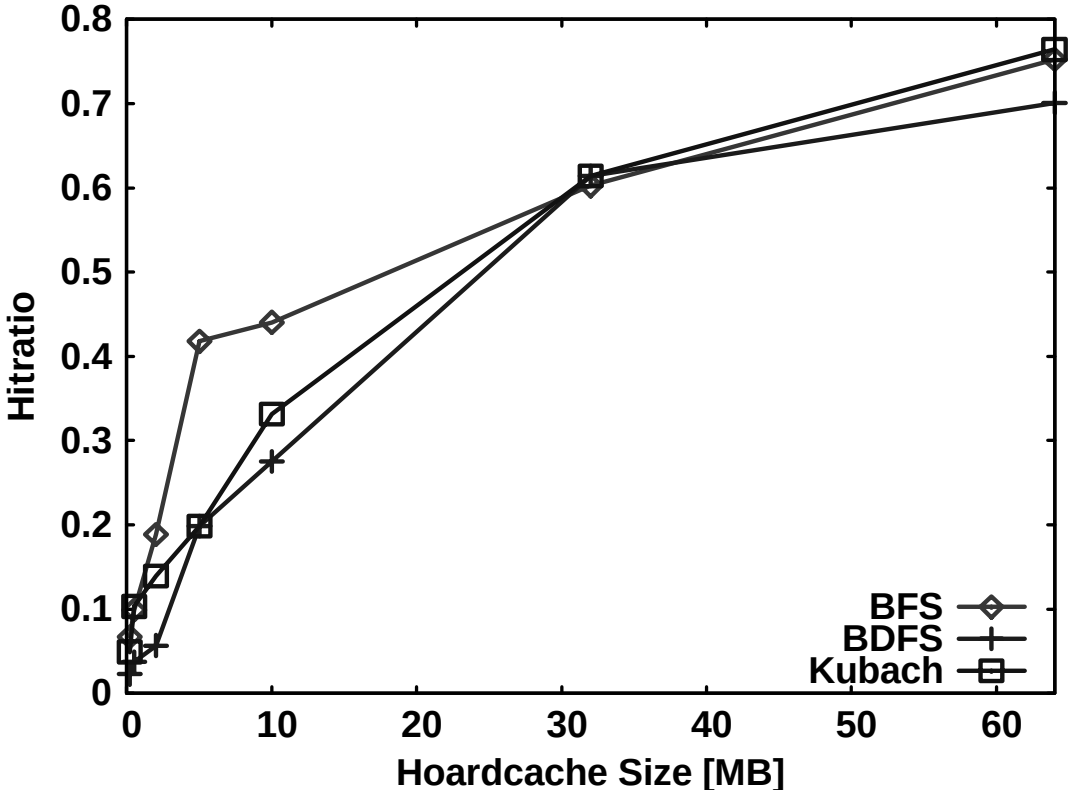


Hoarding: Semantic Distance

- Sessions are mapped to an information graph
- Information graph represents browsing behavior of (a group) of users
- Hoarding decision amounts to graph traversal
  - Breadth-first search algorithm (“shallow” surfing behavior)
  - Depth-first search (in-depths surfing behavior)
  - Algorithms terminate if hoard cache is full



Hoarding: Semantic Distance



Experimental Setup:

- Real-life traces collected on a proxy server
  - 45 user log files extracted
  - approx. 22000 log entries
  - approx. 2000 sessions
- For each hoard-cache size: 20 runs, build average of all measurements

Comparison with basic algorithm (Kubach)

- **BFS** performs ~25% better in average
- **DFS** no gain
- Algorithms show similar performance with increasing cache size

Hoarding: Future Work

- Further methods determining semantic distance
  - evaluation and comparison
- Hoarding of spatial models (structured data)
  - maps, 3D models, …
- Scalable downloading of information at hotspots
  - push approaches: broadcast disks, indexing-on-air
  - pull approaches

Summary

Context-aware applications need spatial models

Vision: Federated world models, shared by many applications

Research goals of Center of Excellence Nexus

Communication can profit from spatial models

- Geocast and Contextcast
- Hoarding

Thank you!

Contact:

Kurt.Rothermel@informatik.uni-stuttgart.de

http://www.nexus.uni-stuttgart.de/