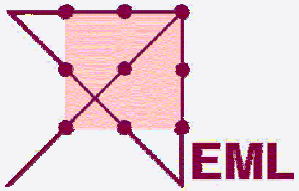
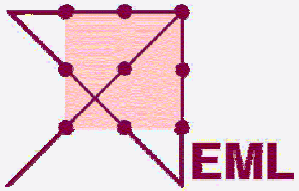


Putting Things in Context

The Next Challenge in Mobile Computing

Andreas Reuter
EML Research gGmbH
European Media Laboratory GmbH

Trento, February 3rd, 2005

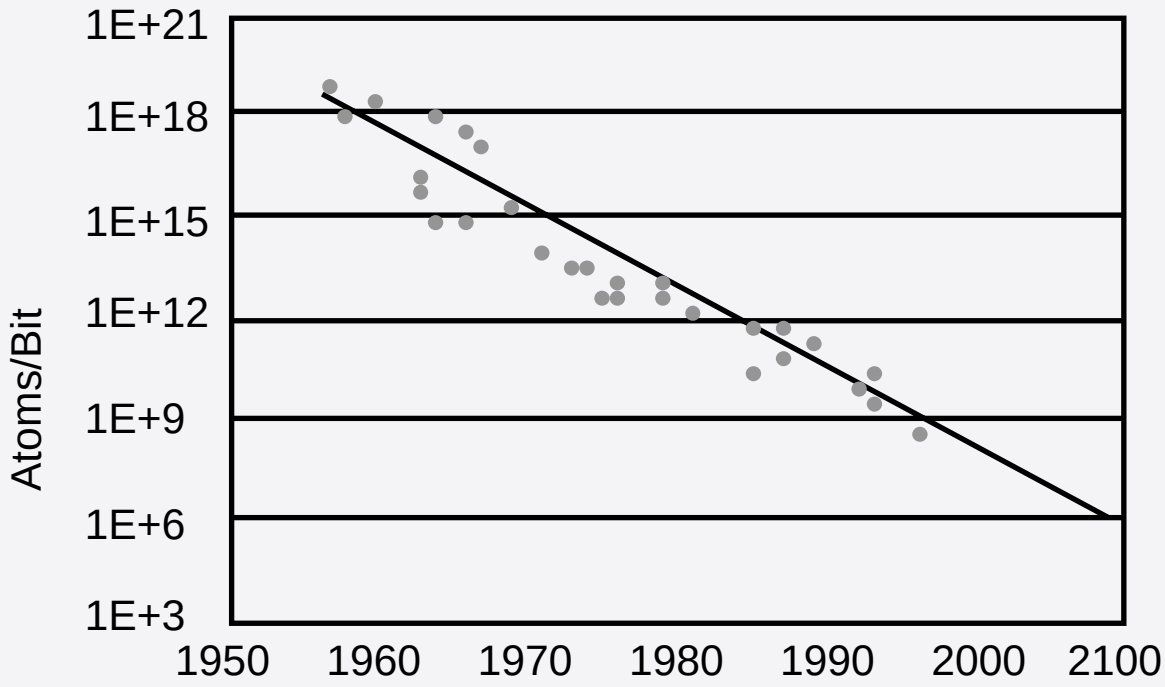


Mobile Computing

- What is it?
  - Trends, terms, definitions, related buzzwords
  - Applications
  - Some examples, projects
  - Challenges
  - What are the issues?
- And what about ….
  - Pervasive computing
  - Mobile computing
  - Smart spaces
  - Invisible computing
  - Utility computing
  - Ambient intelligence
  - Wearable computing
  - Swarms, sensor networks
- What is the same, what is different?

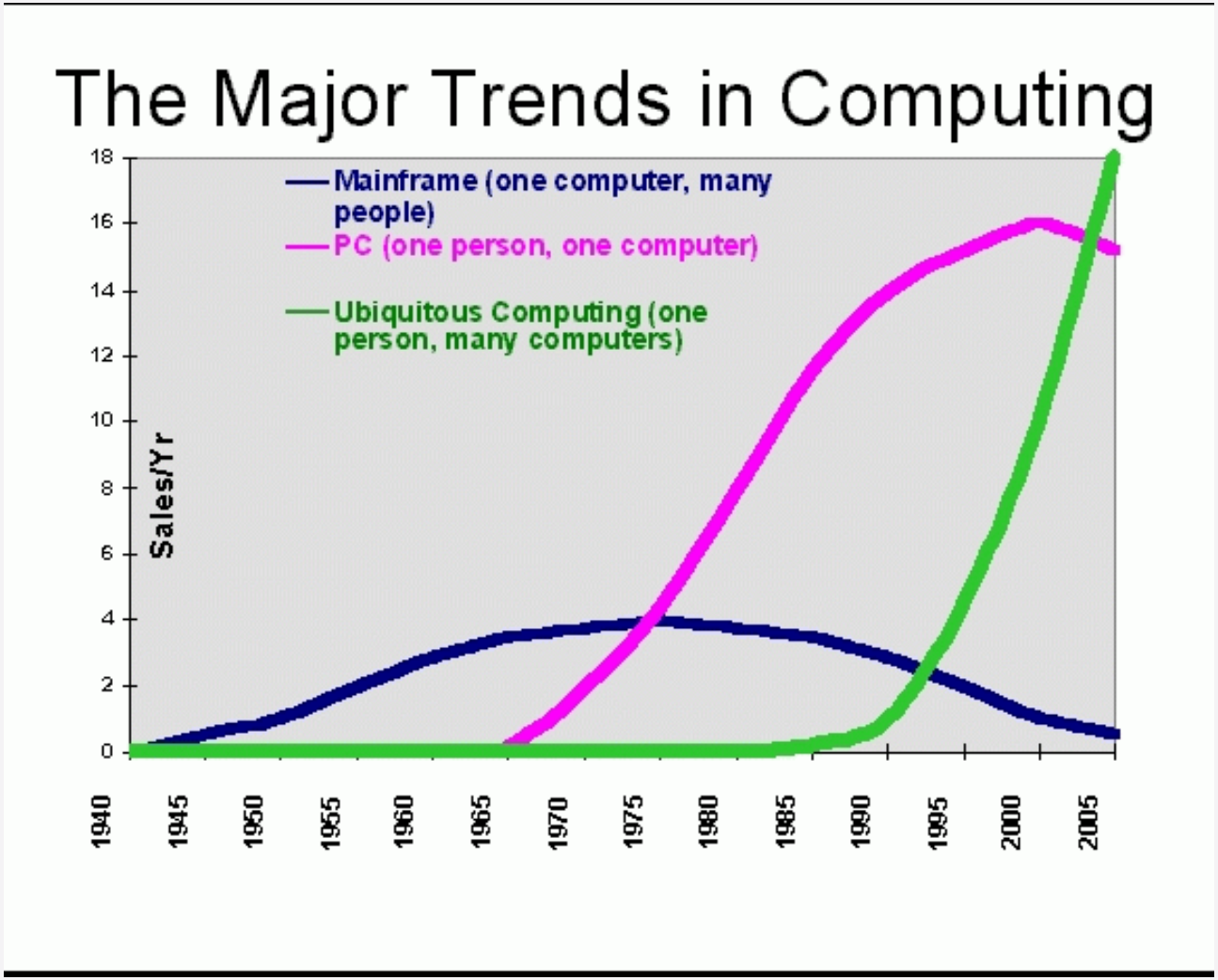
The Obvious Trends

- Moore‘s Law.
- Everything doubles every 18 months.
- About 1 billion transistors per chip in 2007.
- We already reached the phase of smoking hairy golf balls.
- Storage gets faster slower.
- Software becomes the main obstacle.

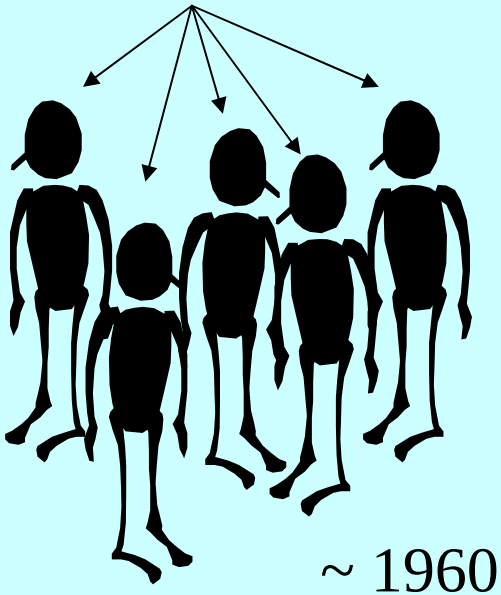


One Attempt at an Explanation

Quoted from Mark Weiser, 1998

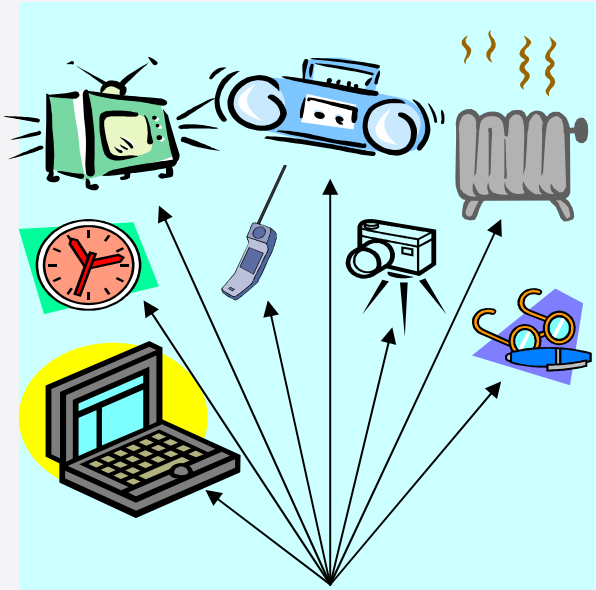


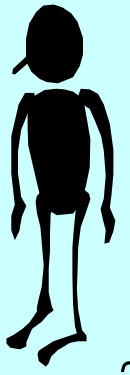
Person/Computer Ratio Is Approaching 0



~ 1960

~ 1980





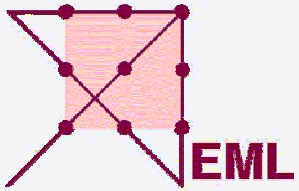
~ 2000

Related Trends

- Networking
  - Also similar: increasing bandwidth + wireless
- New Materials
  - New displays (e-paper, flexible LCDs, …)
  - Fibers
- Sensors (and actuators)
  - Location sensors (GPS etc.)
  - Transponders without power supply
  - Miniature cameras
  - Biometric sensors
- Consequences:
  - Smaller devices
  - Mobile devices
  - Embedded systems

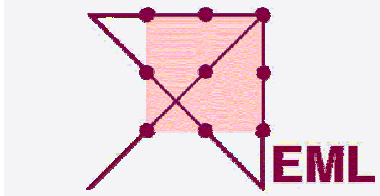
Perspective ...?

- Human/Computer-Ratio = 0
- Swarms, sensor networks, smart dust etc.



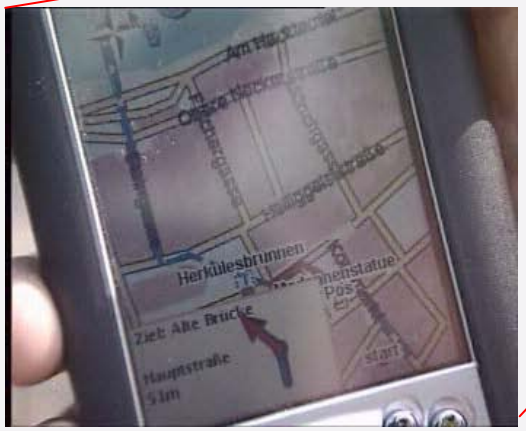
Is That It?

- The problem with these definitions is that they reflect a purely technological view of things.
- But when you consider the usage perspective, it turns out that both „mobile computing“ and „ubiquitous computing“ are misnomers.
- A typical „ubiquitous computing“ device will not be used for computing by anybody. It will do a lot of computing inside, but that is irrelevant from the user‘s point of view – for the same reason that nobody would call a car a „mobile combustion engine“ or something like that.
- Mobile computing is about helping people solve real-world problems, and the question is: How does that affect the processing model and all related issues?



Pure Computing Proper – Guaranteed Context-Free

Mobile/Ubiquitous „Computing“

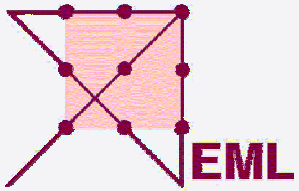


Principles of Ubiquitous Computing I

- The goal of classical computing is to retrieve, interact with, or manipulate some data with relation to the real world.
- The interest of a user of a mobile device is not to interact with the computer but to get support in his real-world endeavours.
- E.g., a tourist who visits a city is interested in finding optimal routes to his target locations, visiting sights or eating in a restaurant.
- In general, users are not interested in the technicalities of an IT-system.

Mobile Interaction

- Technical aspects:
  - smaller displays
  - keyboard input is slower
  - mouse-interaction is not predominant
  - voice control is more practical
  - less standardized and high variability in their input and output capabilities
- Human aspects:
  - the focus of attention lies not on the device
  - the user does other things concurrently (walking, driving, ...)
  - many stimuli from the environment distract the user
  - there are more time-constraints
- Wide range of mobile applications
  - mobile versions of interesting services
  - techniques for computer-mediated interaction with the environment
  - expected to be become the high-volume end of the GRID spectrum



Principles of Ubiquitous Computing II

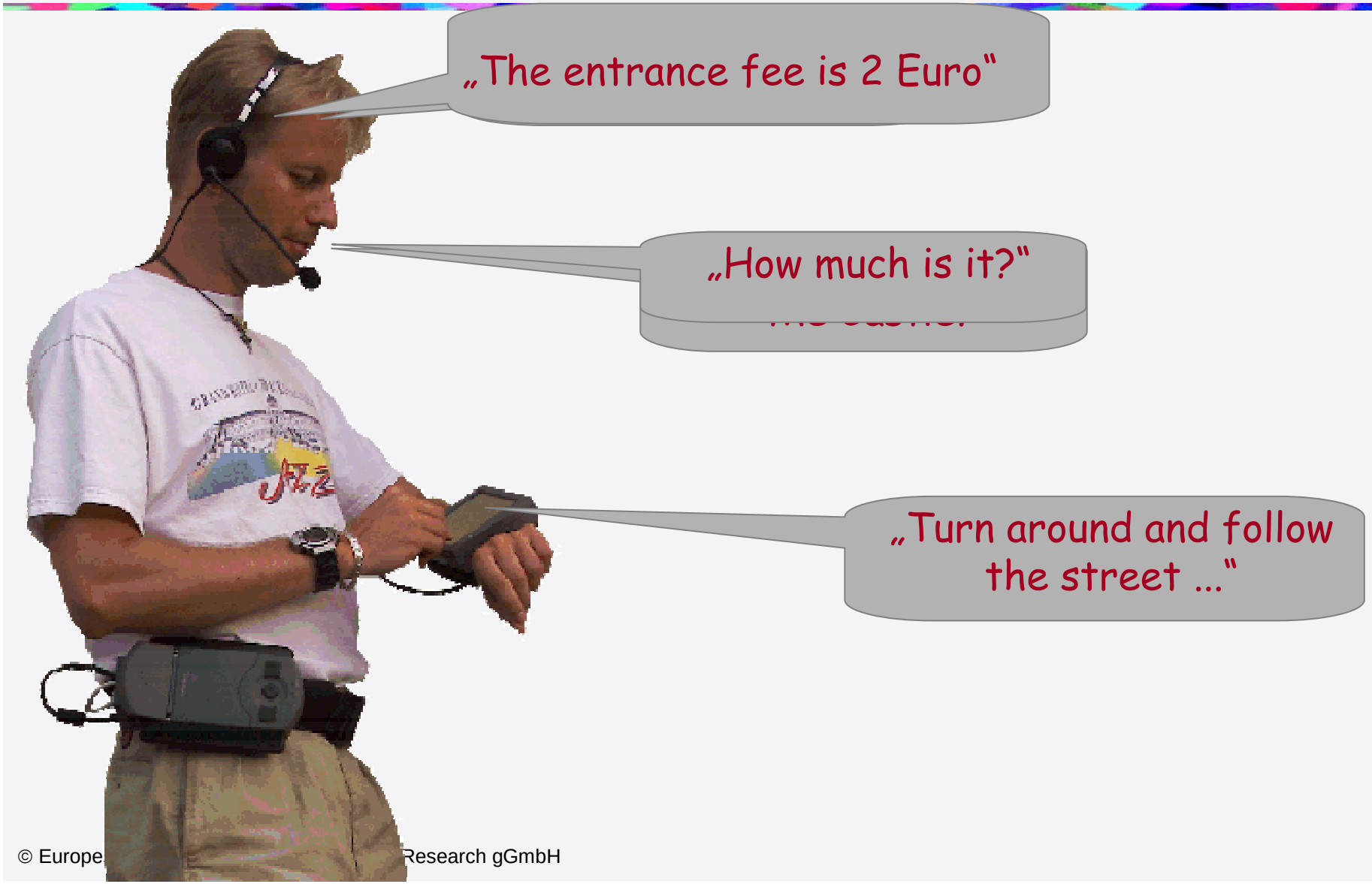
- The goal is to develop technology that disappears as such, but rather becomes an extension of the users' own capabilities.
- "We throw a ball and do not make our arm throw it." – in other words: The UC interface is not a programmer's interface.
- The best computers according to that definition are ...
  - quiet and invisible servants;
  - use natural communication channels;
  - adapt to the user's context and situation;
  - anticipate the user's goals and intentions
  - adapt to the devices available.
- In principle, it is yet another attempt at creating the "Do what I mean" interface.

Context and „Where is?“

relevant factors:

- granularity
- previously mentioned
- dialog history
- understandability
- location knowledge
- intention
- ...

Questions and Answers

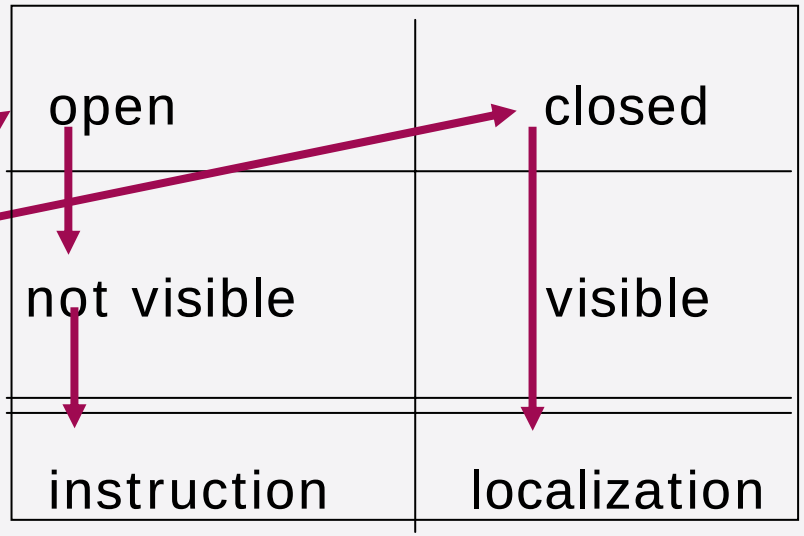


Context

Do not demand input from the user if her intentions can be inferred from the context.

Where is X?

Is X (e.g., *cinema, bank)*



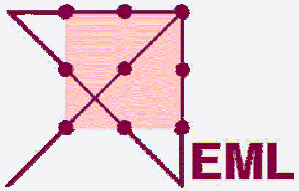
context

t.o.d.

location

How much is X?

Compute possible paths between concepts (like COST und CASTLE) in the ontology and take context into account.



A Simple (?) Example

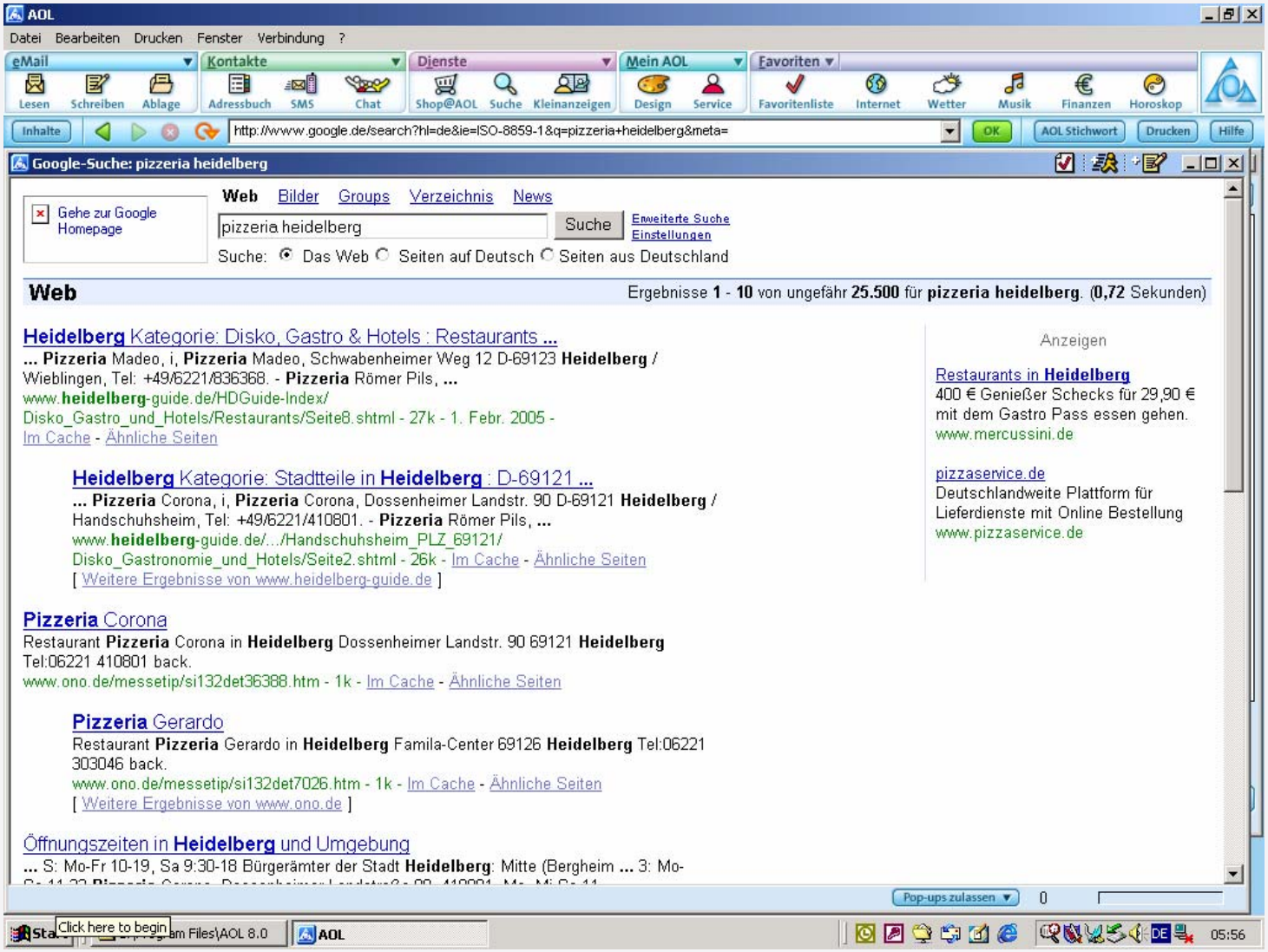
Let us consider a portable city guide for tourists.

EML is running a project that is aimed at building such a device for tourists visiting Heidelberg – but, of course, similar problems would arise when designing a system for Trento, or Rome, or San Fransciso. (Tokyo would be a different matter, though.)

Now assume a tourist using such a device has been walking around for two hours (following the guide‘s recommendations) and now would like to have a meal.

What would be the proper interface for issuing such a request?

The Web Interface



A More Intuitive Interface

What if the user could interact with the system like this:

„Is there a Pizzeria somewhere?“

What could (and should) influence the answer generated by the system?

The Quest for a Pizzeria – Part I

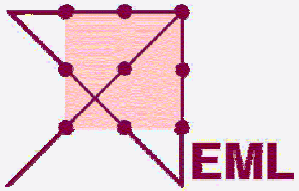
As a first attempt, let us parse the utterance.
In order to emphasize the structure of the sentence, we will re-phrase it accordingly:

Is it true that there exists
an object of type = **x** and
category = „Pizzeria“
in an area = **x** ?

In a more formal notation:

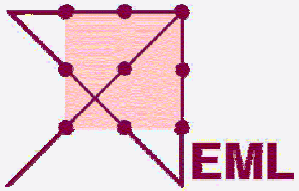
```
if (select count(*)
    from ?
    where type like „*Pizzeria*“ and location = ?;) = 0) then
   answer = „no“                                    else
   answer = „yes“;
```

These bindings have to be determined via context.



The Quest for a Pizzeria – Part II

- Clearly, even though the utterance is a yes/no-question from a linguistic perspective, it should not be treated as such.
- The user model suggests that the person is not interested in an abstract discussion of Heidelberg‘s restaurant profile; it is more likely that the person is hungry.
- Taking that personal context into account, the system should provide a list of Pizzerias, sorted in increasing distance from the user‘s current perspective.
- Coming up with an answer like this refers to four types of context models: the restaurant domain, the user/world model, the activity model, and the spatial model.



The Quest for a Pizzeria – Part III

- Depending on how detailed the context models are, the system can try to adapt to the user‘s needs even better.
- For example, if the user can‘t walk too much and the closest Pizzeria is too far away, the system can direct the user to a different (type of) restaurant or recommend to use a taxi.
- If we include temporal context, the system might even be able to handle the situation where the question for Pizzeria is asked at 11 pm, when normal restaurants don‘t take orders anymore.

Having Analyzed the Pizza Dilemma …

- Now assume the tourist had not asked for a Pizzeria, but had uttered a structurally identical question, such as:

  Is there a brewery?

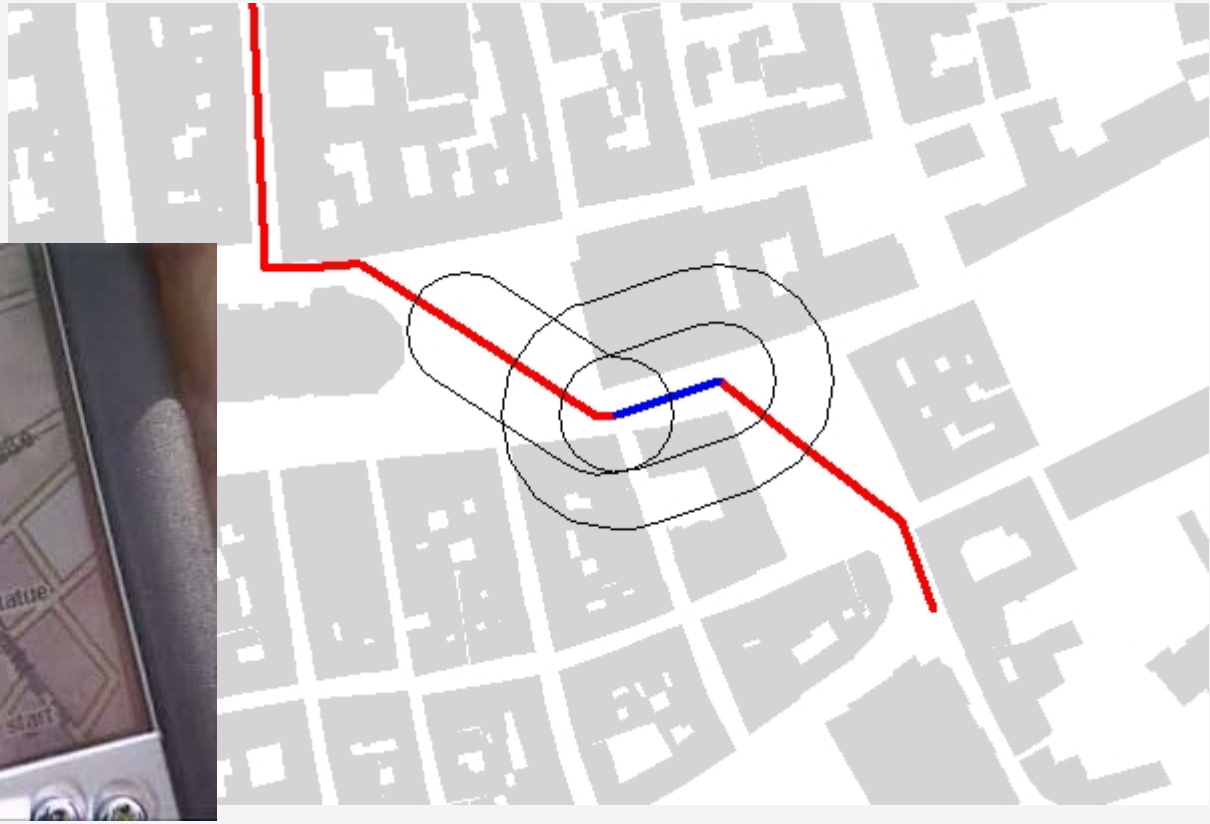
- As in the Pizza example, it is a yes/no question, but in contrast to that example, the user probably does not want to be informed immediately about how to get there and – in case it closed – get re-directed to a distillery.
- Ask yourself what kind of answer you would expect. Maybe „Yes, it‘s called ‚Heidelberg 1602‘.“ would be good enough.

SmartKom Mobile

Start the movie

Route-Instructions

Location-dependent Triggers

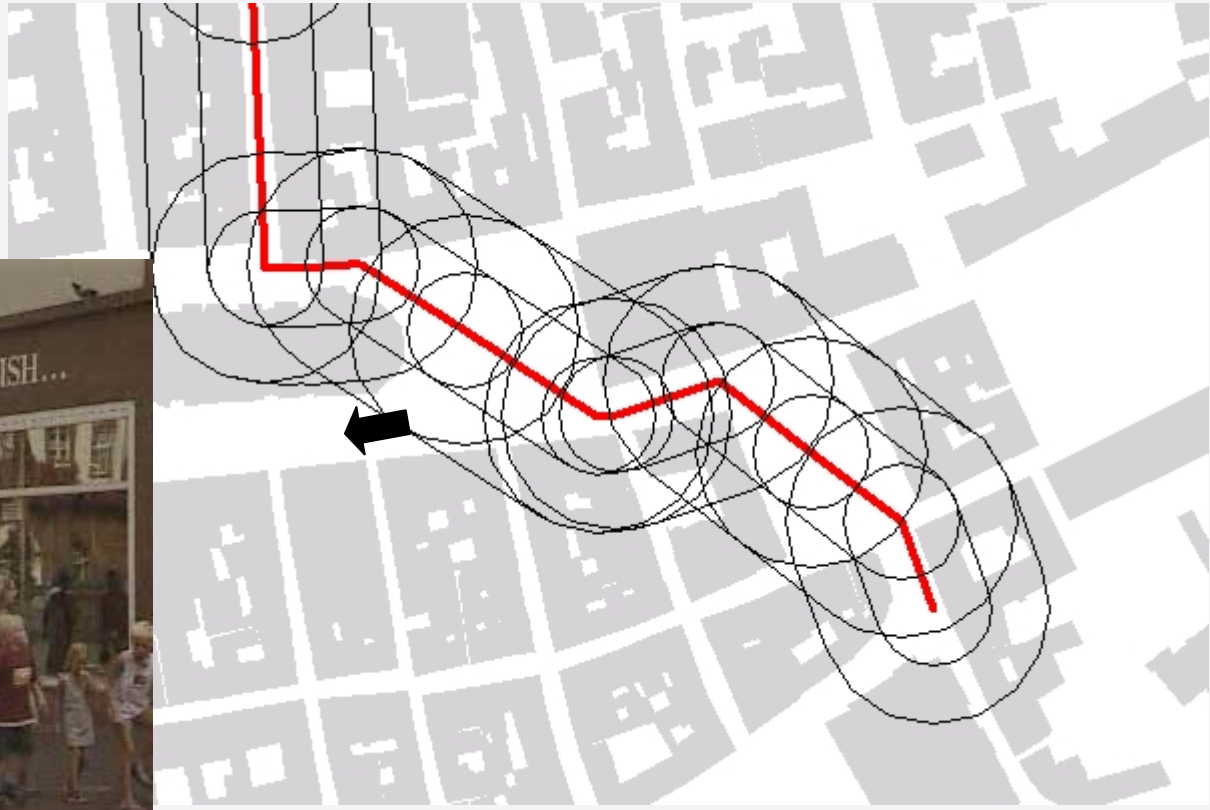


Sights

Notification of near-by sights

Navigation - Corrections

Re-calculation of route to target location in case the original route is abandoned



Smart Living Room: Experiment I

"Please record the thriller tonight"

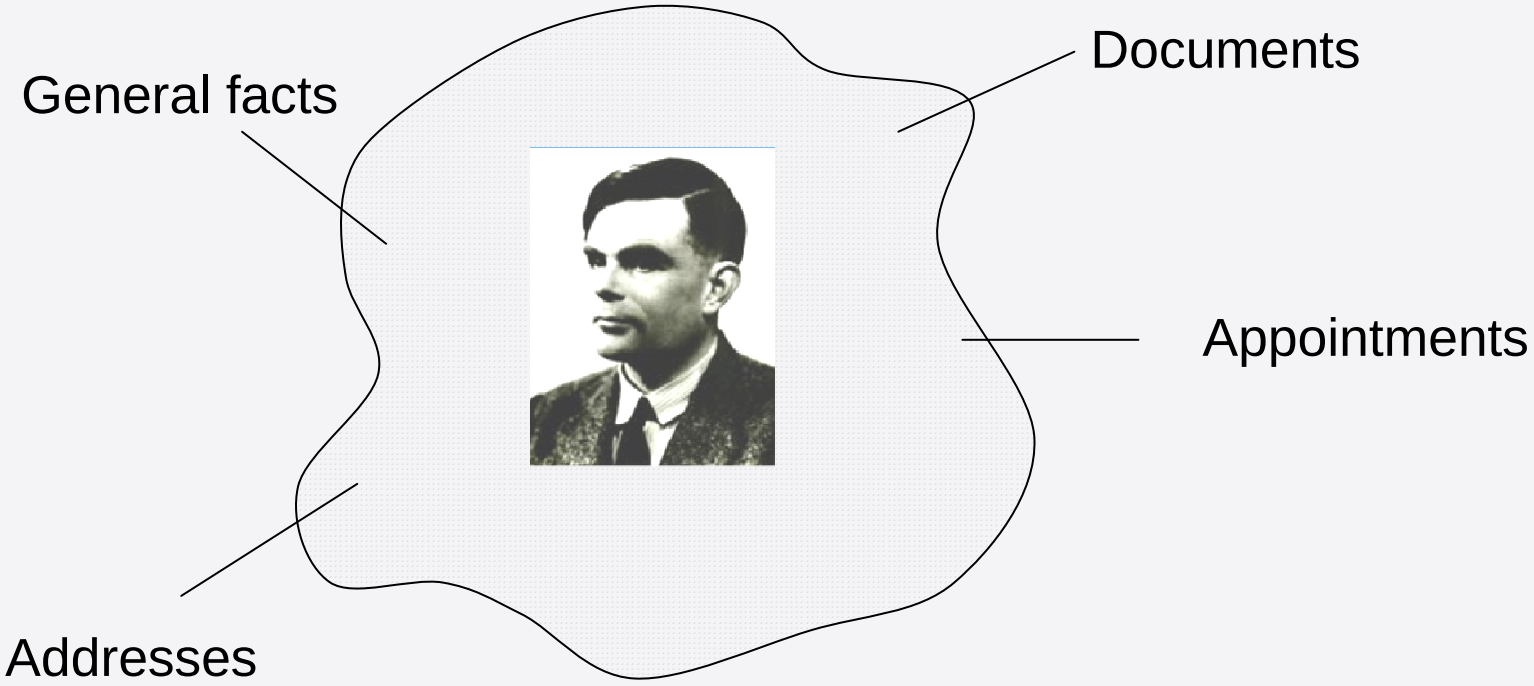
Smart Living Room: Experiment II

"Brighter, please"

Smart Living Room: Experiment III

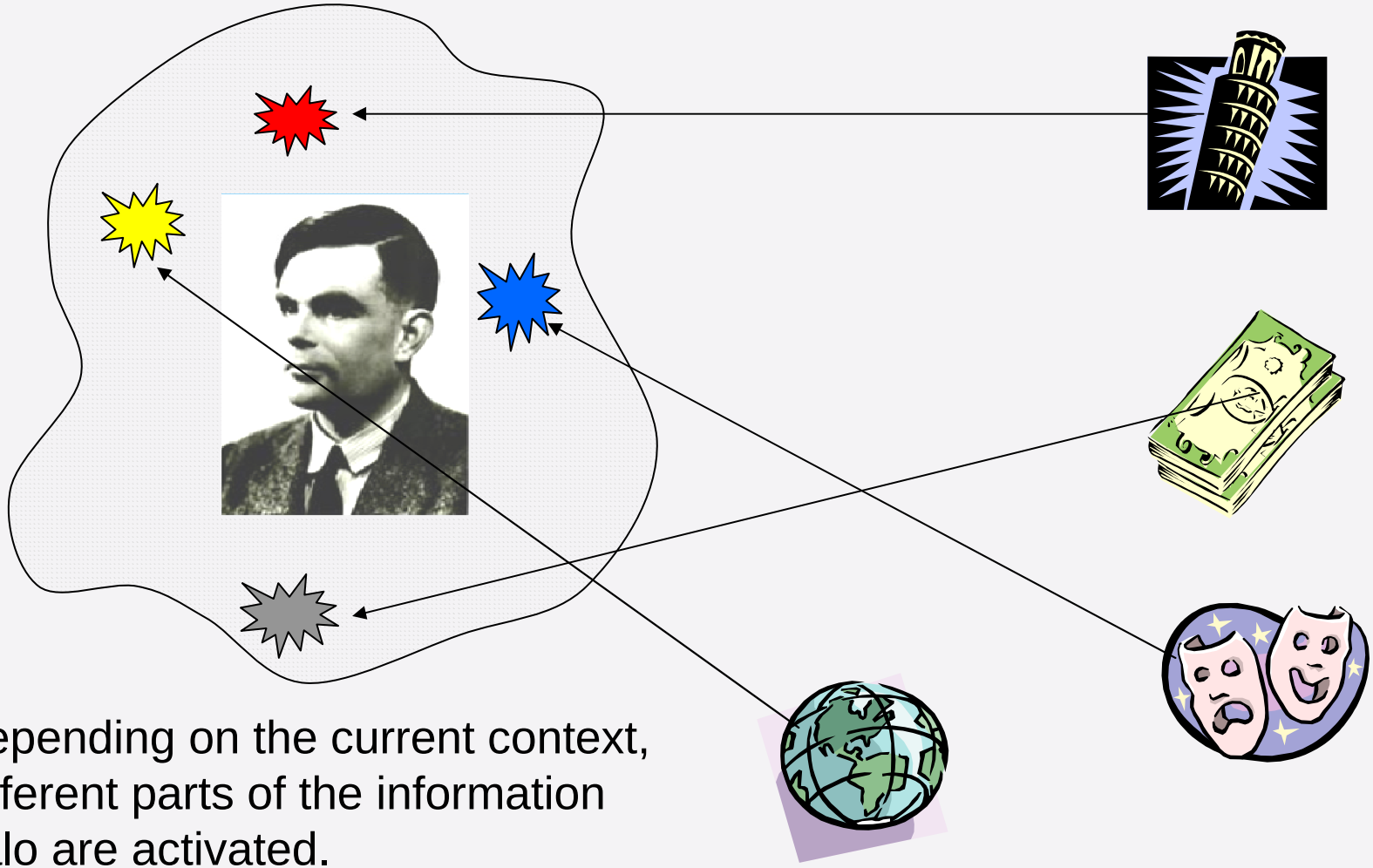
"Brighter, please"

The Information Halo



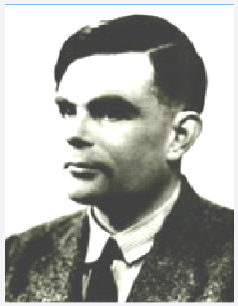
Each person is surrounded by a „halo“ of information, part of which is specific to the person, while other parts pertain to certain groups, activities, etc. – or to the world as such. Large portions of this halo are not stored in the active memory, but may become relevant at some point in the future.

Context Dependency



Depending on the current context, different parts of the information halo are activated.

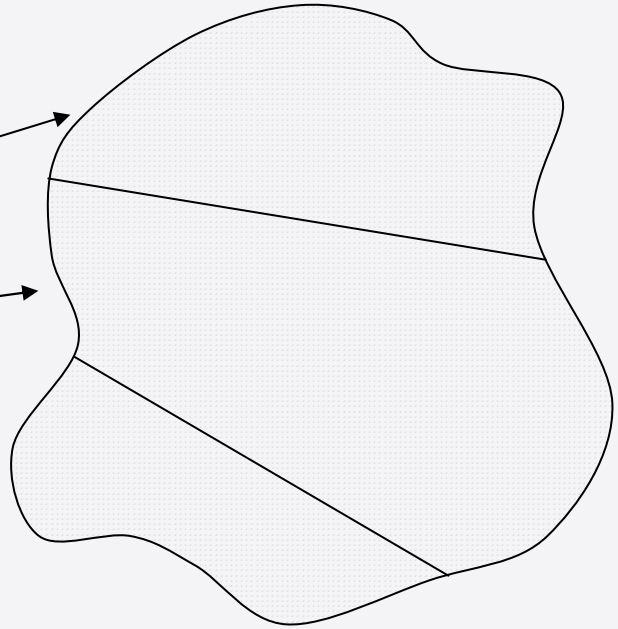
Typically ....



Books, notes,
„back of the
envelope“

Phone

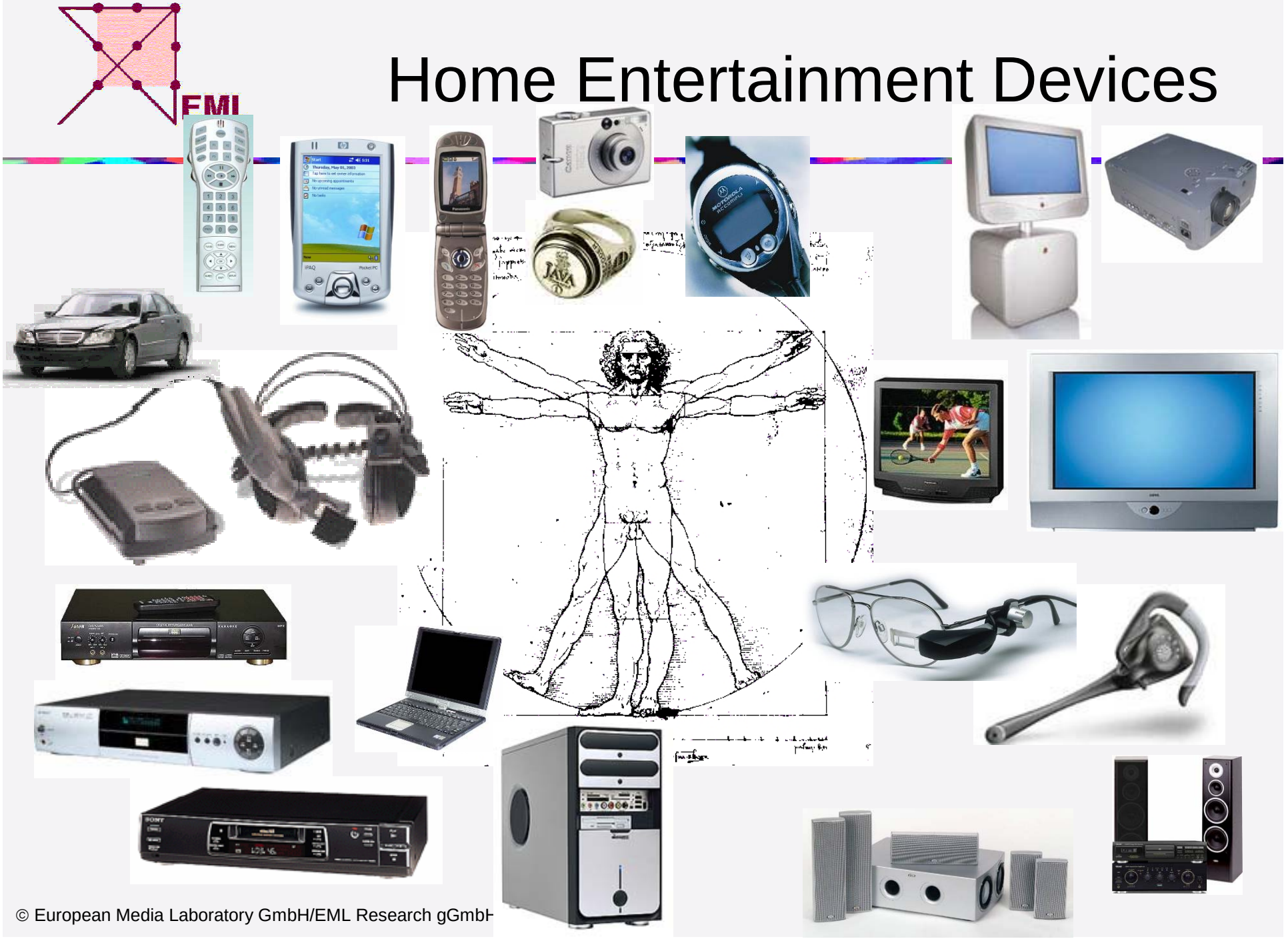
PC, PDA etc.



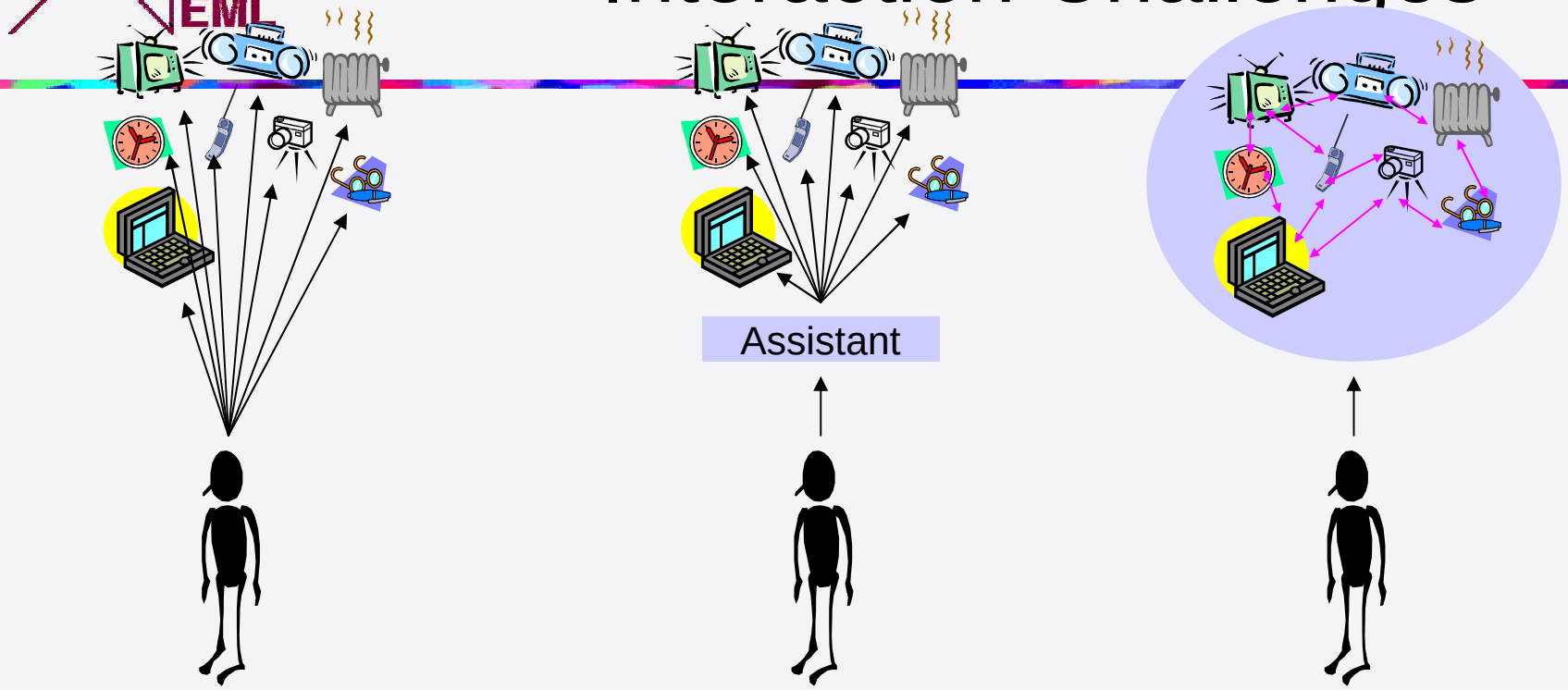
... the information is kept on different devices and thus accessible only in structurally different ways.

Pictures from Nerdvana

Home Entertainment Devices



Interaction Challenges



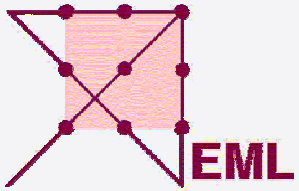
Command & Control
by User

Command & Control
by Central Component

Command & Control
by Self-Organization

Speak the language of the user - be multimodal, i.e. allow the user to interact in a natural way (voice, gesture).

Coherent multimodal interfaces.



Home Entertainment

- Heterogeneous:
  - Each household has different devices
  - Different suppliers
  - Different resources (e.g., connectivity, resolution, …)
- Dynamical:
  - Devices are switched on/off, brought in/taken away
  - Software updates
- Networked:
  - TVs for Internet browsing
  - Stereos for MP3 download
- Open
  - Connected to car, office, mobile
- Goal: Realization of Intelligent presentation management
  - flexible device change
  - multi-device and multi-media presentations:
  - Contents must be integrated semantically
  - Adaptation to resources

Home Entertainment

What is the difference?

Appliances We Love to Hate …

- Internet portals for the kitchen (Ariston Leon@rdo)
- Fridges with internet (Electrolux Screenfridge)
- Paper Notepads with HWR (A.T. Cross Crosspad)
- Telephones with Internet (IBM Screenphone)
- Electronic Books (Gemstar REB 1200)
- Internet-Connected Picture Frames (Ceiva Logic, Inc.)
- … and SmartPhones, PDAs, Digital Cameras, Portable MP3 Gadgets, Set-Top-Boxes, etc.

And There Is Furniture ...

- Roomware®: Integration of walls, doors, tables, chairs into a pervasive computing environment.
- It will
  - diagnose problems, provide information, establish connections between people, and offer "help".
  - adapt to changing situations and provide context-sensitive information according to knowledge about past and current states or actions and, if available, even about plans of the people.

www.roomware.de

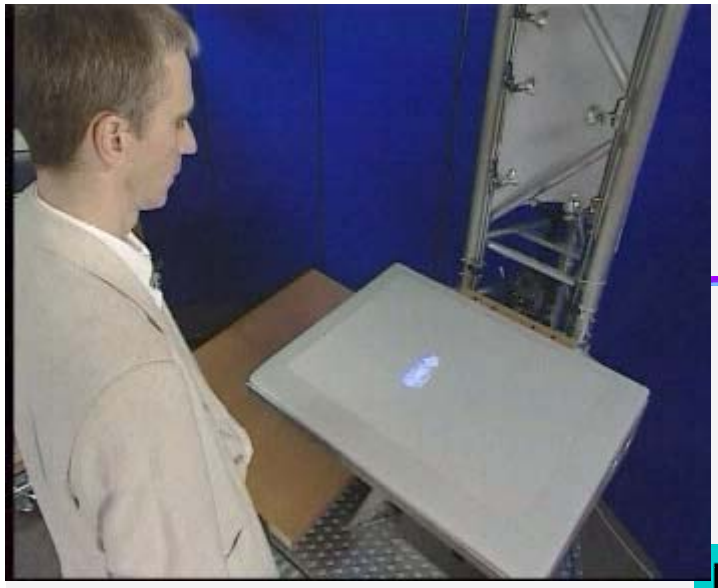
… and Cyber Homes

Fraunhofer Innovation Center
Intelligent House Duisburg
www.inhaus-duisburg.de

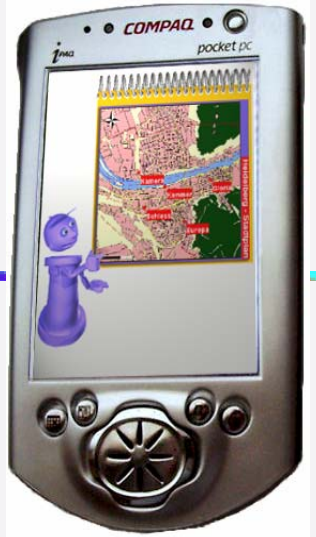
Georgia Tech
Aware Home Research Initiative
www.cc.gatech.edu/fce/ahri/

A New Kind of Access Gap

- Due to the use of different media, **all** information is accessible only if and when all media are available and can be used – i.e. almost never.
- The obstacles are numerous:
  - From a car, access to large files,images etc. is severely limited.
  - Pedestrians typically don‘t do a lot of browsing, and they don‘t carry lots of books.
- The user‘s situation changes quickly: leave the care, walk around, back to the car, etc.
- The notion of having specialized devices for every external situation will probably not be accepted by a wider user community.



Mobil



Navigation for cars and pedestrians

Consumer Electronics

Public

Mensch-Technik-Interaktion
Smart KOM

Home

LMU

MediaInterface

ISI

DFKI

Chair for Pattern Recognition
FAU Erlangen-Nuremberg

PHILIPS

DAIMLERCHRYSLER

SONY

SIEMENS

Context-Awareness – Examples

Smartkom

Home scenario

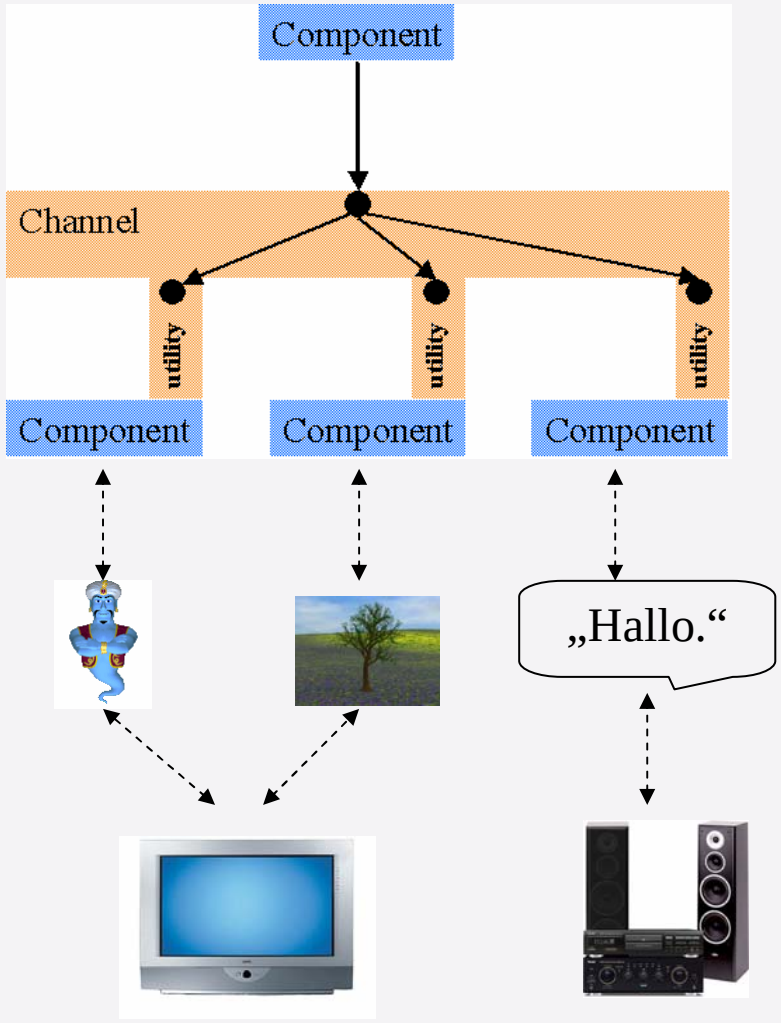
Context parameters:

- User's Location,
- Time,
- Interaction history

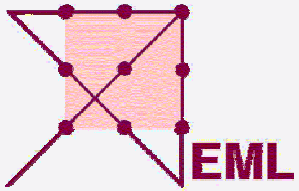
Mobile scenario

Public scenario

Adaptive Presentation Architecture



1. Output initialization
2. Presentation strategy
3. Output components
4. Multimedia ouput
5. Output devices



Outdoor AR for Pedestrians

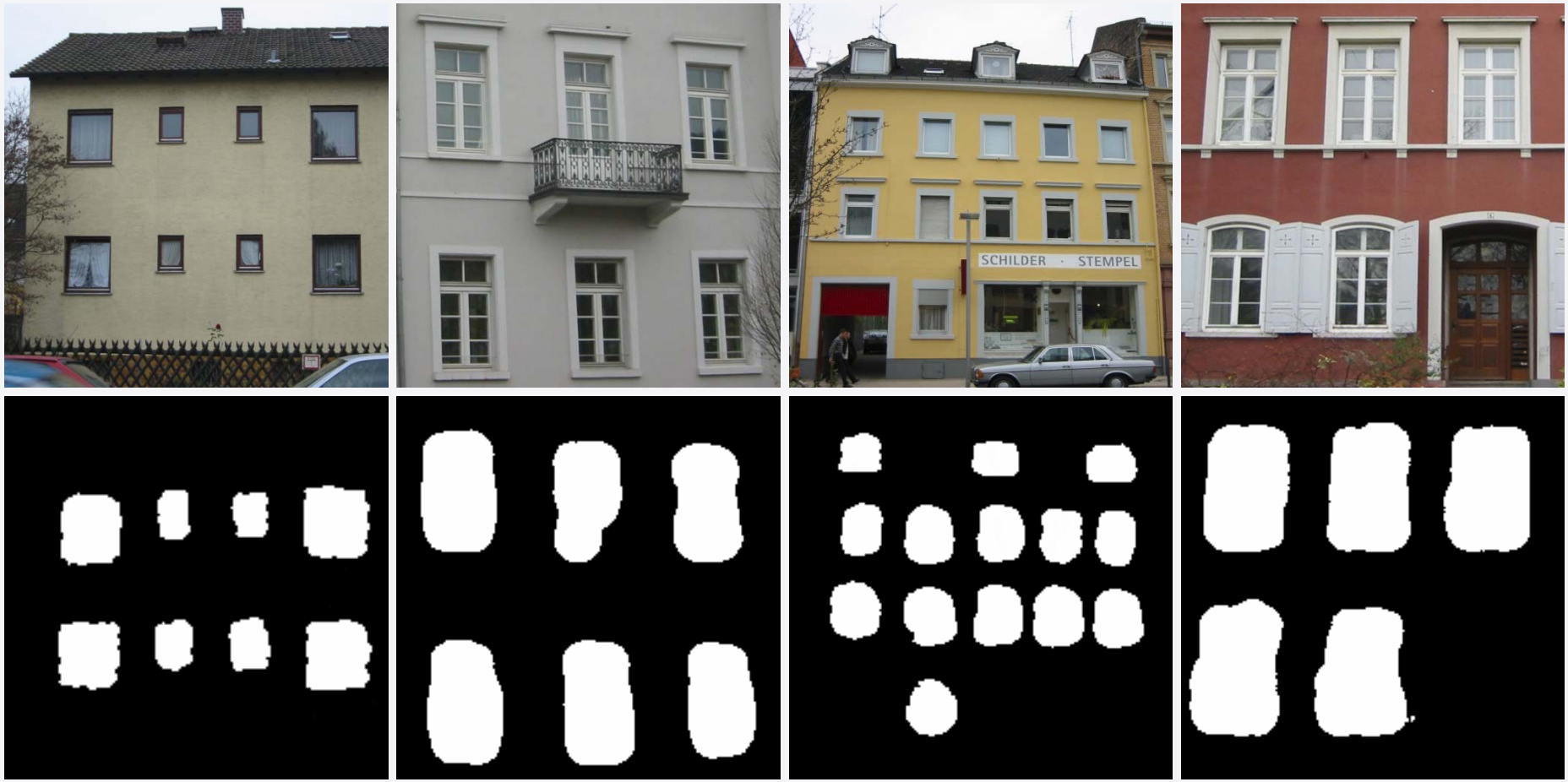
- Tracking needs position and orientation
- Multiple sensors/solutions: GPS, camera, tags, gyroscope, …
- Outdoor systems
  - AR-tags too expensive for full coverage
  - Typically: hybrid systems
  - Often including video based tracking
    - Reference required → problem: gaps in coverage of data
    - Weather condition and seasonal changes are critical
    - Hard to be done in real-time with 25 renderings per second
- Systems today are often
  - Isolated, not scalable
  - Still in research labs, and for limited domains (e.g., medicine)

Start the movie

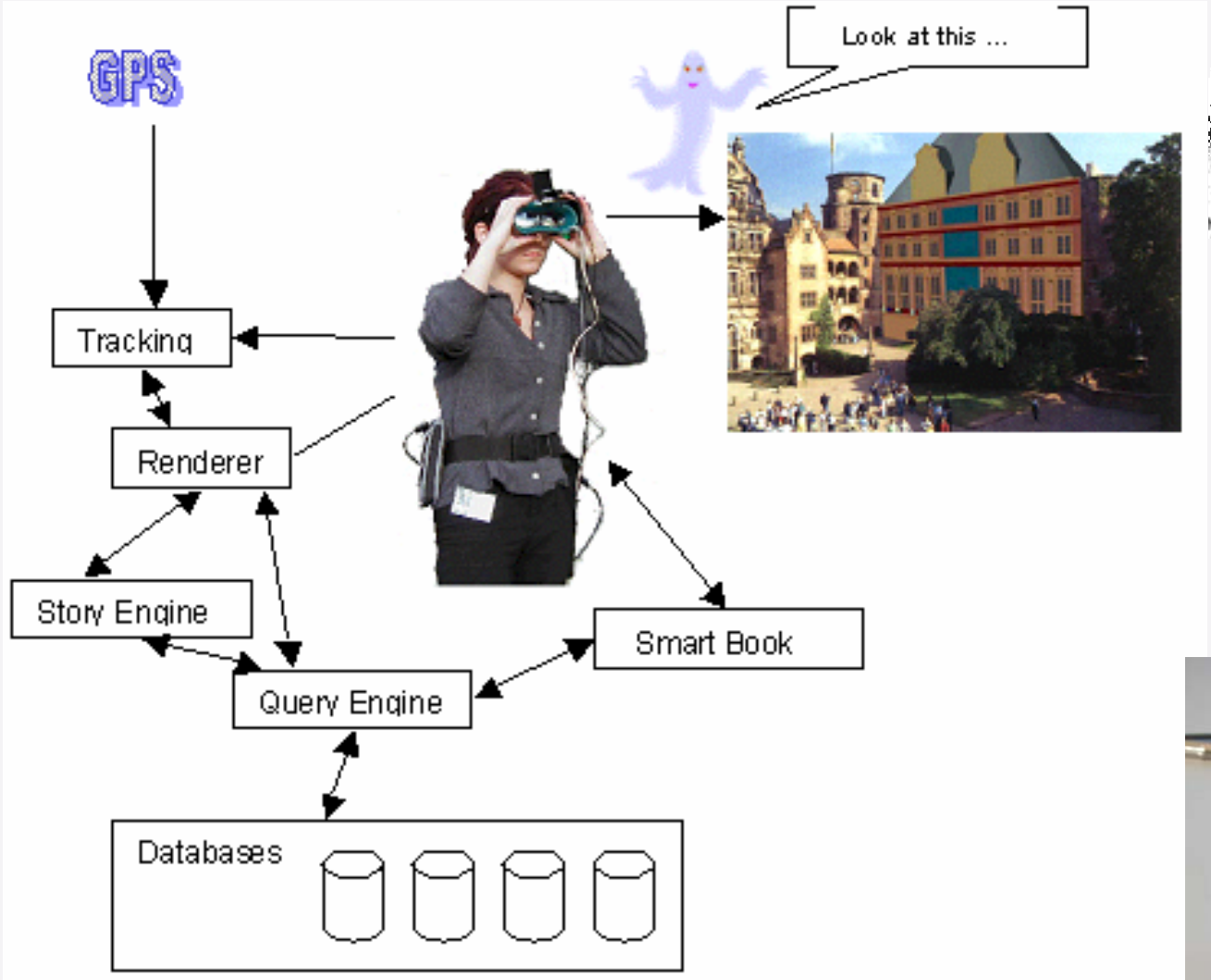
Tracking Devices Used

- Hybrid:
  - DGPS
  - Orientation tracker (gyro)
  - Camera
  - 3D models
- Sensors are used depending on situation
  - GPS registers when player enters a stage
  - Video tracking for initial adjustment
  - Gyro for tracking of head movement

Image-Based Localization

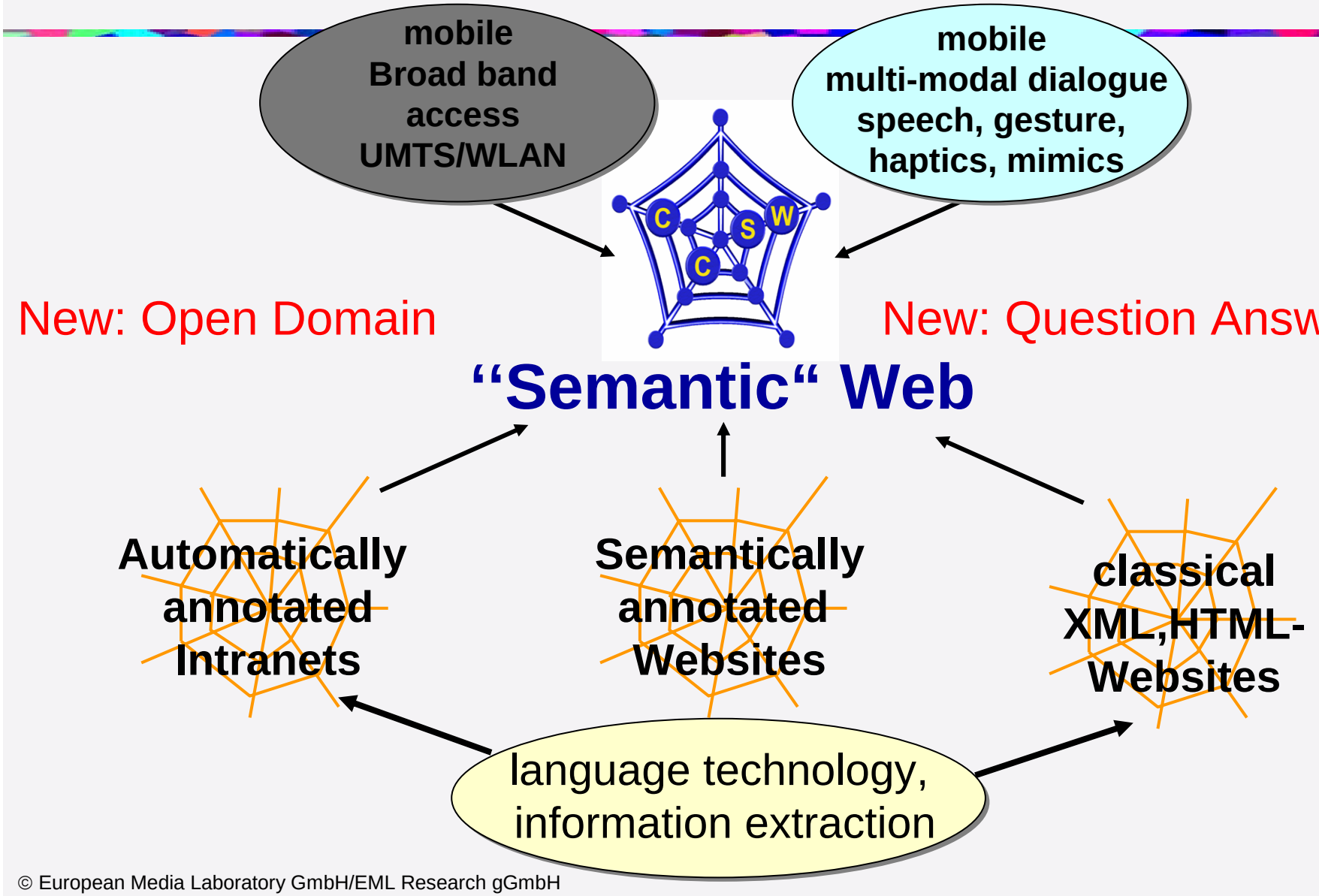


GEIST Components



A Current Project

The Goals of SmartWeb



SmartWeb Modalities

Speech

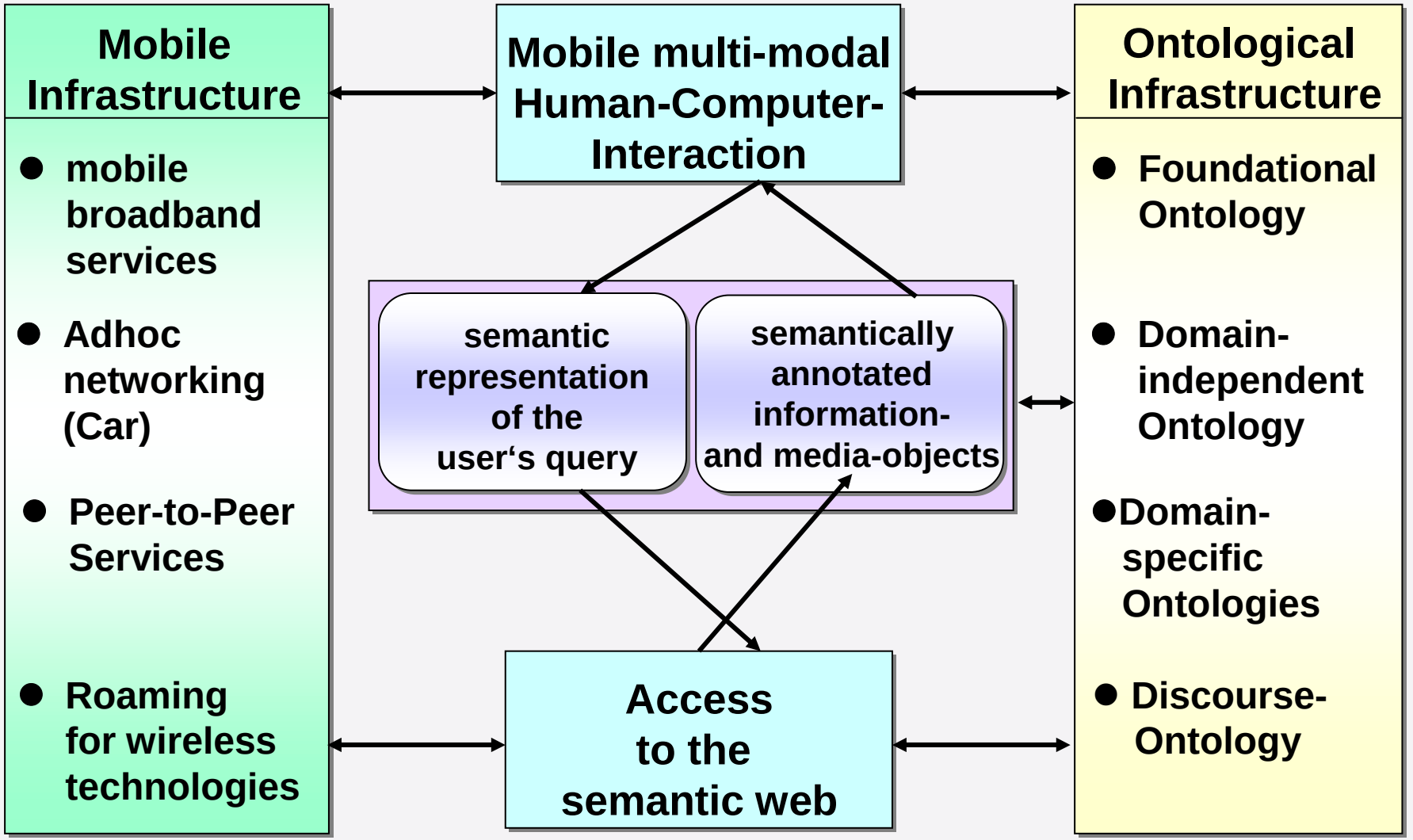
Gesture via Pen

Haptics

Video

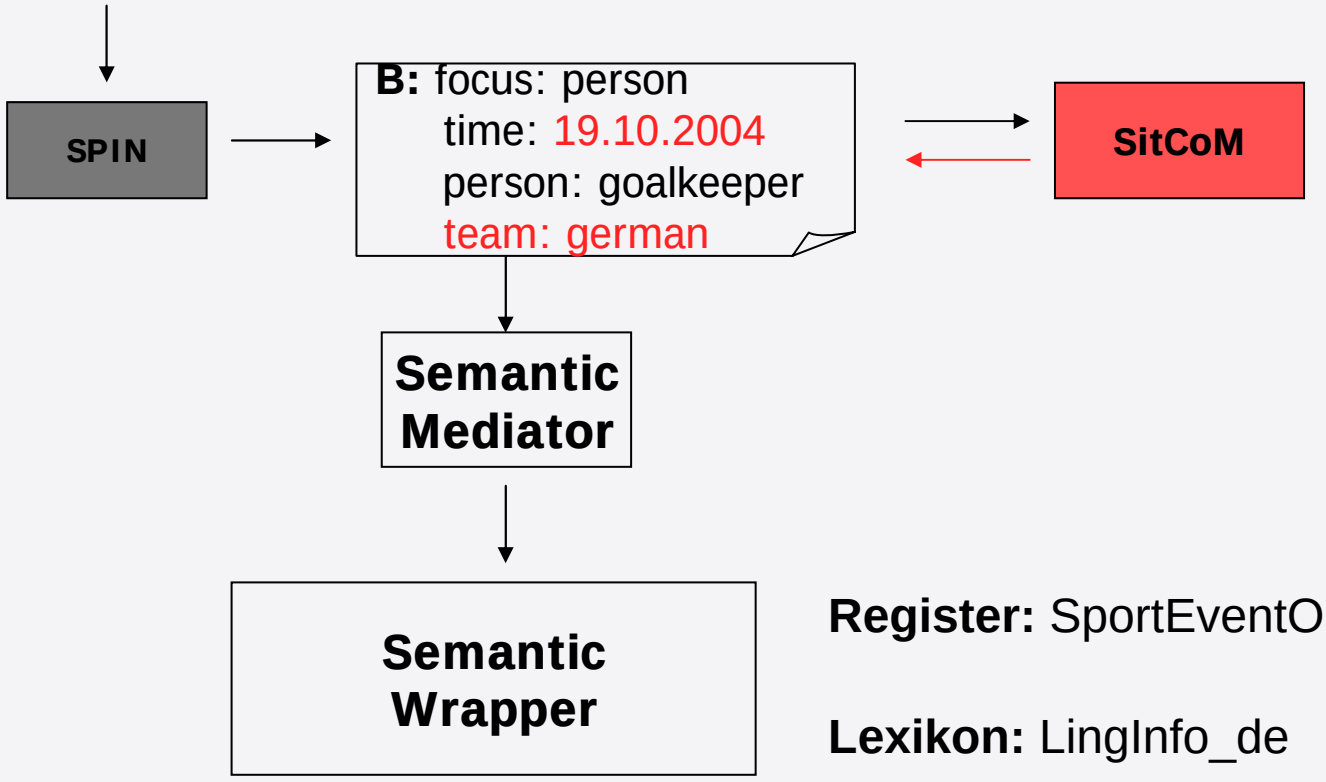
Bio-signals

SmartWeb: Overview



Semantic Wrapper and QA in SmartWeb

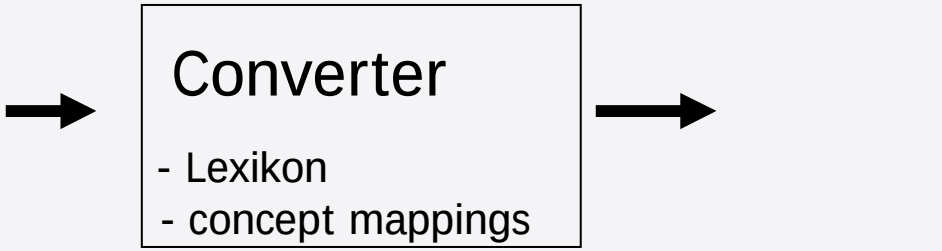
User question: „Who will be the goalkeeper tomorrow?“

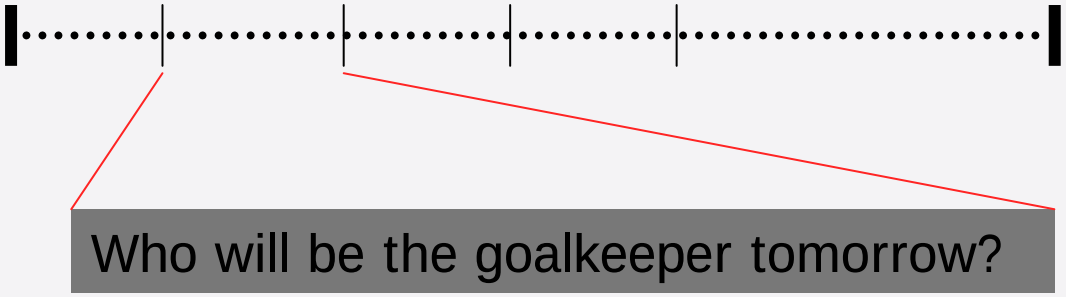


Register: SportEventOntology

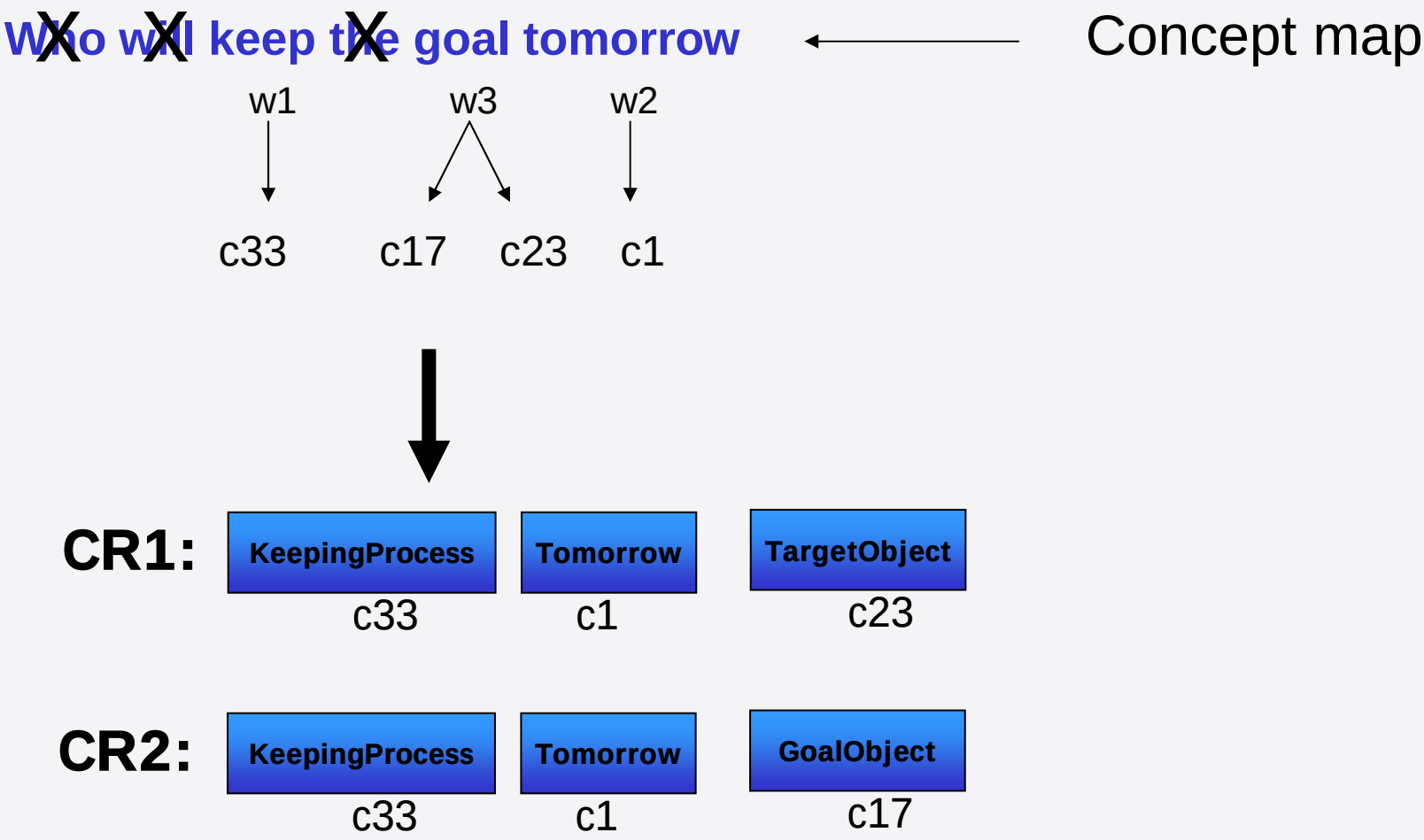
Lexikon: LingInfo_de

Step 1: Chunking

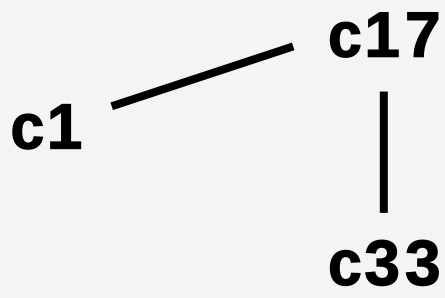


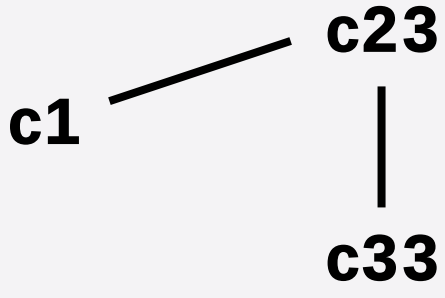


Step 2: Word2Concept Transformation



Step 3: OntoScore

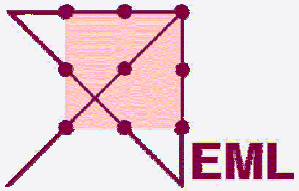




S (CR1) = 0.6

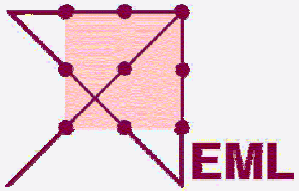
S (CR1) = 0.7

Calculate minimal paths from a source node to all other nodes and select the minimal paths connecting a given concept ci with every other concept in CR (excluding ci); the result is a nxn matrix of the respective paths.



Step 4: Query and Answer

```
<rdfquery>
  <From eachResource=”http://www/soccer#Teams” >
      <Select properties=”Name playesTomorrow”>
          <Condition>
              <equals>
                  <Property name="Name" />
                  <rdf:String>German</rdf:String>
              </equals>
          </Condition>
      </Select>
  </From>
</rdfquery>
```

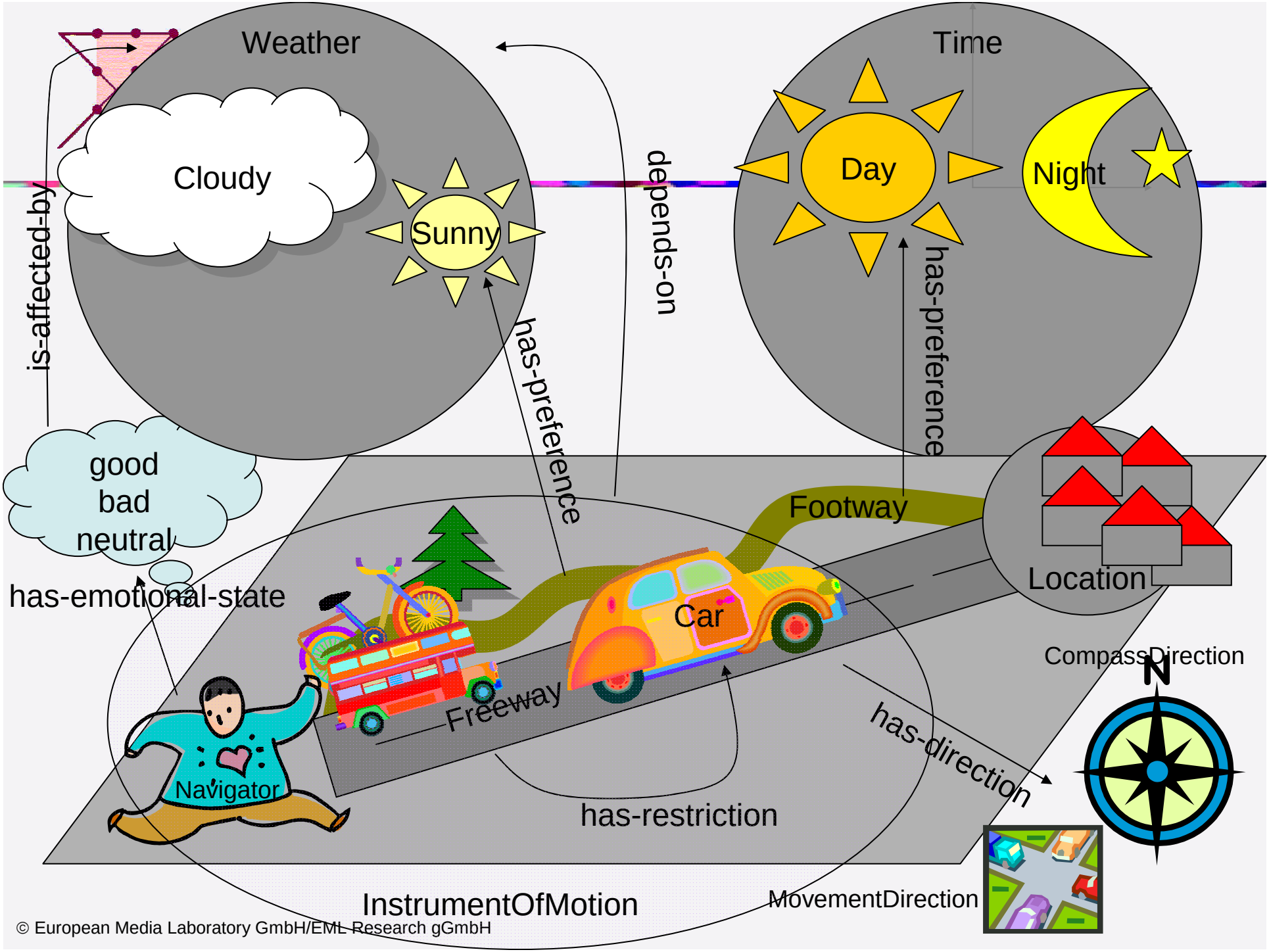


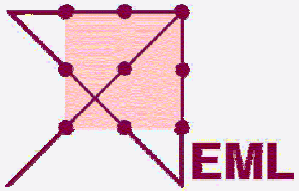
Our Contribution to the Project

- Domain ontologies and ontology learning
- Context-dependent language understanding
- Semantic wrappers for syntactic websites
- Resource-adaptive component and agent technologies

Example of a User Model

- Pedestrians prefer public transportation whenit’s raining.
- Motor bikers prefer side roads, but not when road conditions are poor.
- Car drivers want to get information about road conditions before deciding about a route.





Some Sample Axioms

An Environment is a Parameter valued by WeatherRegion.

Environment(x) -> Parameter(x)
Environment(x) -> Ay.valued-by(x,y) -> WeatherRegion(y)

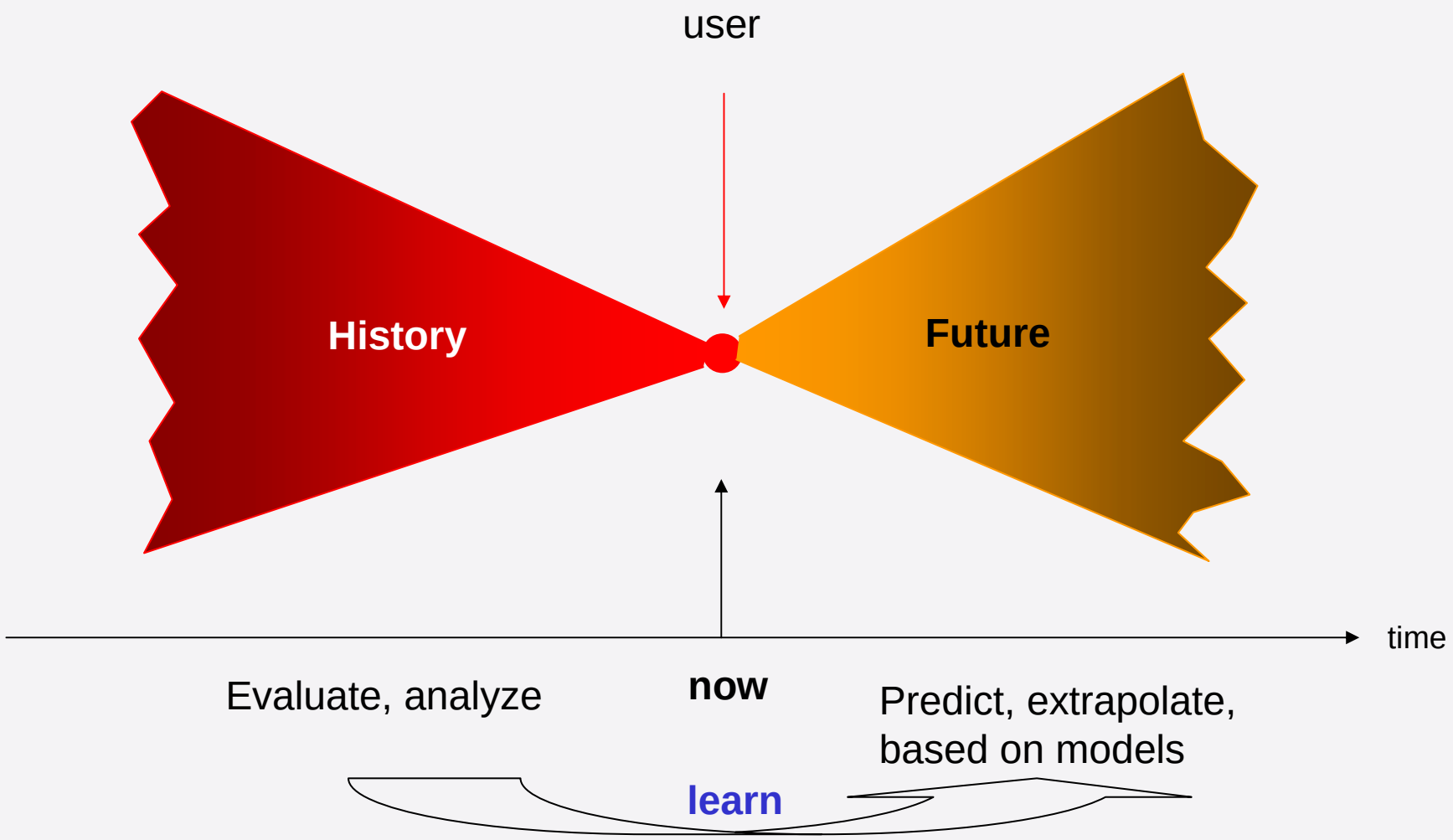
A Path is a Role played by a road in all cases.

Path(x) -> DnS:Role(x)
Path (x) -> Ay.played-by(x,y) -> Road(y)

A Locomotor is a Role played by a Navigator in all cases.

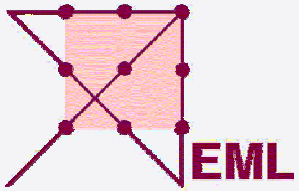
Locomotor(x) -> DnS:Role(x)
Locomotor(x) -> Ay.played-by(x,y) -> Navigator(y)

The Process of Mobile Computing



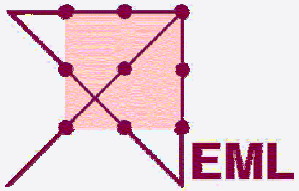
Context Categories

type of context	content	data source
Spatial (static)	position, location	Position sensor, map
Spatial (dynamic)	Trajectory, schedule, goal	Sensor., phys. model, map, time table
Temporary (static)	Date, time, season, period	Clock, calendar, time table, model
Temporary (dynamic)	Log (continuous), log (discrete)	User model, event cal., time table
Physical	Weather, brightness, noise	Sensor, user reaction, dom. model
Personal	Transp. mode, handicaps, etc.	User model, situation model
Dialog	what has been said by whom	discourse model
Activity	Plans, goals, constraints	User model, itinerary
Social	Companions, type of group, etc.	User model, itinerary
Culture	Preferences, taboos, habits	User model, domain model/ontology
Domain	domain/conceptual knowledge	domain model/ontology
Top-level	General facts and rules	World model/ontology



Contextual Programming

- This is the major challenge in building context-aware systems: We don‘t have a good solution to the problem of programming under such conditions.
- Context has to be used for
  - dynamic binding,
  - disambiguation,
  - assigning priorities to competing requests.
- The notion of correctness in classical programming has to be replaced by the notion of „plausibility“; in many cases there is no strictly correct answer.
- Contextual programming basically means matching inputs against a set of models.
- The results (i.e. user responses) have to be used to adjust the models.
- Feedback into the models comes from both individual users for the current activity and from groups of users for the higher-level models.

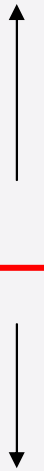


Units of Execution

- Low-level routine 10^{-6} sec
- I/O routine 10^{-3} sec
- Simple interactive TA 1 sec
- Simple query 10^{1} sec
- Complex query 10^{2} sec
- Routine workflow 10^{3} sec
- Simulation / data mining app. 10^{4} sec
- Medium-sized workflow 10^{5} sec
- ...
- WF repr. large construction project 10^{8} sec

Effects: Relevant Values Have Changed

- Low-level routine 10^{-6} sec
- I/O routine 10^{-3} sec
- Simple interactive TA 1 sec
- Simple query 10^{1} sec
- Complex query 10^{2} sec
- Routine workflow 10^{3} sec
- Simulation / data mining app. 10^{4} sec
- Medium-sized workflow 10^{5} sec
- ...
- WF repr. large construction project 10^{8} sec



no

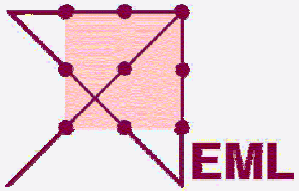
maybe / yes

Effects: History of Execution Is Relevant

Low-level routine	10^{-6} sec	
I/O routine	10^{-3} sec	
Simple interactive TA	1 sec	↑ no / maybe
Simple query	10^{1} sec	
Complex query	10^{2} sec	
~~Routine workflow~~	~~10^{3} sec~~	
Simulation / data mining app.	10^{4} sec	↓ yes
Medium-sized workflow	10^{5} sec	
...		
WF repr. large construction project	10^{8} sec	

Effects: Rules / Assumptions Have Changed

Low-level routine	10^{-6} sec	
I/O routine	10^{-3} sec	
Simple interactive TA	1 sec	↑ no
Simple query	10^{1} sec	
Complex query	10^{2} sec	
Routine workflow	10^{3} sec	
Simulation / data mining app.	10^{4} sec	
~~Medium-sized workflow~~	~~10^{5} sec~~	
...		↓ maybe
WF repr. large construction project	10^{8} sec	



Effects: Program Fully Specified At Start Time

Low-level routine	10^{-6} sec	
I/O routine	10^{-3} sec	
Simple interactive TA	1 sec	yes
Simple query	10^{1} sec	
Complex query	10^{2} sec	
Routine workflow	10^{3} sec	
Simulation / data mining app.	10^{4} sec	
Medium-sized workflow	10^{5} sec	
...		
WF repr. large construction project	10^{8} sec	no

Final Remark

If you ask somebody for driving direction to a particular restaurant, and he says:

„Go to Hell.“

then you either have met a very rude person, or you happen to be in Norway near Trondheim, and the answer is perfectly acceptable – it depends on the context.