Context-aware databases
design, integration and applications

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Bertinoro, March 2008

Motivations

Keywords: mobility, context-dependence, adaptability, multimodality, multi-channel delivery, pervasiveness, ubiquity, navigation, incremental discovery, sensors, power-awareness, computational power, storage space…

- **Many large applications require the decomposition of an information base into (possibly overlapping) subsets**
- **Content and services available at different sources and places**
- **User is an integral part of numerous applications, interacting with:**
  - **service providers, product sellers, governmental organisations, friends and colleagues, sensing devices.**
- **Micro/mobile components of a modern information system:**
  - **PDA, Smartcard, Cellular phone, Embedded system, RFID, Sensor equipped with on-board chip**

Context

- **derived from the Latin** *con* **(with or together) and** *texere* **(to weave),**
- **describes a context not just as a profile, but as** *an active process dealing with the way humans weave their experience within their whole environment, to give it meaning***.**

Example

Automated support for a natural history museums visitors, endowed with a portable device which reacts to a change of context by

- **adapting the user interface to the different** *abilities* **of the visitor – from low-sighted people to very young children –;**
- **providing different information contents based on the different** *interests/profiles* **of the visitor (geology, paleontology, . . . scholar, journalist, . . .), and on the room s/he is currently in;**
- *learning*, **from the current situation and the previous choices performed by the visitor, what information s/he is going to be interested in** *next*;
- **providing the visitor with** *appropriate services* **– to purchase the ticket for a temporary exhibition, or to reserve a seat for the next in-door show on the life of dinosaurs –;**
- **deriving** *location information* **from sensors which monitor the user environment;**
- **providing knowledge of the** *sorrounding people* **in terms of their roles and respective contexts,** *as related to the user*
- **providing** *active features* **within the various areas of the museum, which alert visitors with hints and stimuli on what is going on in each particular ambient.-**

Accordingly...

- Context contributes to the meaning that must be inferred from the adjacent world
- Such meaning ranges from the references intended for indefinite indications such as "take that" to the shared reference frame of ideas and objects that are suggested by a situation
- Context goes beyond immediate binding of variables to the establishment of a framework for communication based on shared experience
- Such a shared framework provides a collection of roles and relations to organize meaning for a piece of information

Accordingly, context involves...

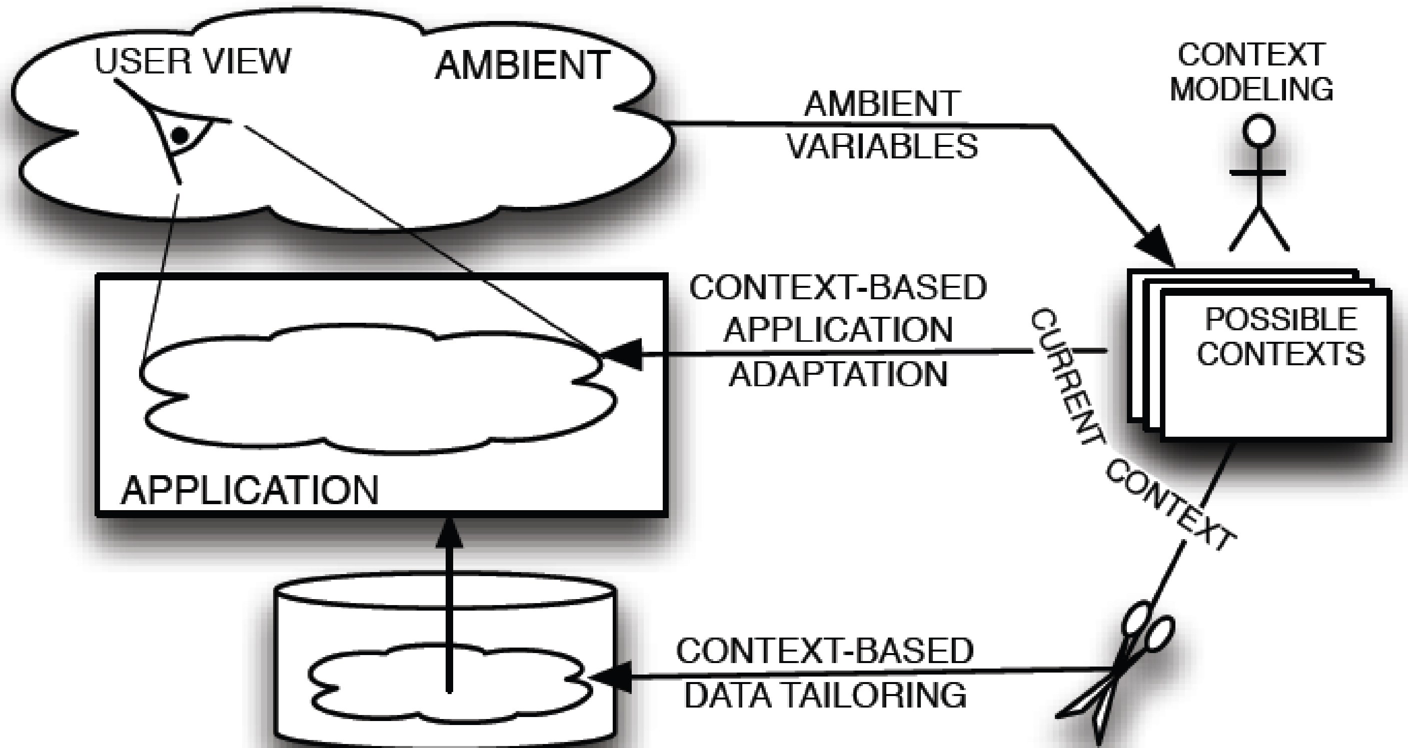
- *viewpoint* **- classifying items according to a viewpoint of some agent**
- *topic* **- any item in the information base is relevant to one or more topics, such as marketing, Canada, etc.,**
- **the setting of** *focus* **by ignoring issues not relevant to a specific situation,**
- **the modeling of limited availability of or restricted** *access* **to certain kinds of information,**
- **the description of situations with** *varying degree of evidence* **as in reasoning processes or in cooperative work,**
- *time slot* **- viewing an entity from just one instant of time as opposed to representing all the properties it gathered throughout its entire life-time.**

Underlying, often implicit principles

- **Principle 1 (Locality): reasoning uses only part of what is potentially available (e.g., what is known, the available inference procedures). The part being used while reasoning is what we call** *context* **(of reasoning);**
- **Principle 2 (Compatibility): there is compatibility among the kinds of reasoning performed in different contexts.**

(*Chiara Ghidini, Fausto Giunchiglia,* **Local Models Semantics, or Contextual Reasoning = Locality + Compatibility,** *Artificial Intelligence, 2001*)

A context-aware architecture



The six "W" questions of context

1. What is context?
2. Who might benefit from an awareness of their context; whose context is important to whom, or what?
3. Where can an awareness of context be exploited?
4. When is context-awareness useful?
5. Why are context-aware applications useful?

Answers to these five questions underpin the higher level, meta-question of:

6. hoW do we implement context-awareness so that we can develop context-aware applications?

(Proceedings of the CHI 2000 Workshop on "The What, Who, Where, When, Why and How of Context-Awareness", David R. Morse, Anind K. Dey, 2000, Georgia Institute of Technology)

What is context?

Context

- Different meanings in different realms of Computer Science
- Is context a matter of….?….

Is context a matter of….?

(a) capability to *adapt content presentation* **to different channels or to different devices**

(b) modeling *location and environment* **aspects**

(c) modeling what *the user is doing*

(d) *agreement and sharing* **among groups of peers**

(e) *service/data reduction*

HOW ??

Categories for context model interpretation – Modeled Aspects

- **Space:** whether the system manages location
- **Time:** whether the system takes into account the time dimension
- **Space/Time Coordinates:** whether the space and time are represented absolutely (e.g. Global Time and GPS coordinates) or relatively (e.g. "near something", "last month", "after that")
- **Context History:** whether the history of contexts is part of, or relevant for, the context itself, or instead the context is considered as a static picture of the current instant
- **Subject:** the point of view used to describe the context itself: context as if perceived by the user, or from the application point of view (the user itself is a portion of the context)
- **User profile:** if and how the user is represented (profiled) within the context model

Categories for context model interpretation - Representation

- **Fomalism Type:** the class of formalism used to capture the context (e.g. ontologies, OO model, frames, etc.)
- **Flexibility:** is it possible to capture any context with this model?
- **Level of formality:** how formal is the model
- **Variable granularity management:** ability to model context aspects at different levels of detail
- **Constraints on valid contexts:** whether the system provides ways to control the generation of invalid contexts

Categories for context model interpretation – context usage

- **Context construction:** run-time vs. design time construction; centralized vs. distributed construction
- **Context info quality monitoring:** is it possible to control and correct automatically acquired context info (e.g. when sensors are present)?
- **Reasoning:** whether the context model enables reasoning on context information to obtain more abstract or more complex context descriptions
- **Ambiguity and incompleteness management:** in case of ambiguous or incomplete context information, is the system able to ``interpolate'' somehow the context information and reconstruct a plausible ``current context''?
- **Automatic Learning Features:** whether the system includes context learning features, e.g. by observing user behavior during browsing the system may autonomously learn user's preferences
- **Multi-context representation:** the possibility to represent in a single instance of the model all the possible contexts, as opposite to a model where each instance represents a context.

What is context?

Is context a matter of….?

(a) …capability to adapt content presentation to different channels or to different devices:

- Different levels of granularity
- Often do not include a refined mechanism of location and time awareness
- User profiling is often present, feature-based
- Context specification quite informal
- Not very flexible (designed for specific applications)
- Automatic context learning (often available)
- No context reasoning

Is context a matter of....?

(b) ...modeling location and environment aspects

- **Precise treatment of the time and space coordinates**
- **Ability to model the context in a highly flexible way**
- **Context reasoning provided, offering a powerful abstraction mechanism**
- **Information quality control, since in this case the system acquires location and time information from various kinds of sensors**
- **Ability to deal with information ambiguity**

Is context a matter of....?

(c) ...modeling what the user is doing

- Context history is modeled
- Reasoning mechanisms are needed
- Time and space are taken into account as related to the user's current activity
- Different levels of formality
- Automatic learning (available in some systems) used to guess user activity from sensor readings

Is context a matter of....?

(d) ... agreement and sharing among groups of peers

- Focus on reaching an agreement about a context shared among peers
- Context definition reached in a distributed fashion
- Context reasoning is present
- Quality monitoring is present
- Ambiguity and incompleteness are managed
- Context model rather well formalized
- Primitive treatment of location, time and user profiling

Is context a matter of….?

(e) …services/data reduction

- Selection of data, but also of relevant functionalities and services
- Time, space and user profile highly developed and well formalized
- Possibility to describe different kinds of contexts, thus flexibility is high
- Variable level of granularity
- Constraints on valid contexts can be expressed
- Context history and reasoning often not provided

A survey on Context Models

Context-aware databases
design, integration and applications

Bertinoro, March 2008

Context models in computer science

Conceptual CM **considers the context notion** *not only as a state, but as a part of a process*

- Context as "any information that can be used to characterize situation"
- Situation refers to the current state of the environment
- Context specifies the elements that must be observed to model situations
- A process-based software architecture.

→ **Conceptual CM** *tailors services and information to the current situation*

Conceptual CM (Coutaz, Crowley, Dobson, Garlan)

- Context is about evolving, structured, shared information spaces, spaces designed for a specific purpose. Challenges:
  - **Recognize users' goals and activities**
  - **Map these goals and activities adaptively to the population of available service and resources**
- Context-as-a-process is more flexible than context-as-a-state
- The utility and usability of a system are derived from the emergence of information and cooperation rather than the sophistication of its individual components
- Danger:
  - **Mismatch between the system's model of interaction and the user's mental model of the system**

Conceptual CM (Coutaz, Crowley, Dobson, Garlan)

- Perceptual processes provide a means to detect and track compositions of *entities* and to verify *relations* between entities
- The design problem is to determine the appropriate entities (resp. relations) that must be determined (resp. verified) with respect to a task or service to be provided, in a potentially infinite set
- The "state" of an environment is defined as a conjunction of predicates
- The environment must act so as to render and maintain each of these predicates to be True
- Environmental predicates may be functions of information observed in the environment, including:
  - **position, orientation and activity of people in the environment**
  - **position, information and state of other equipment**

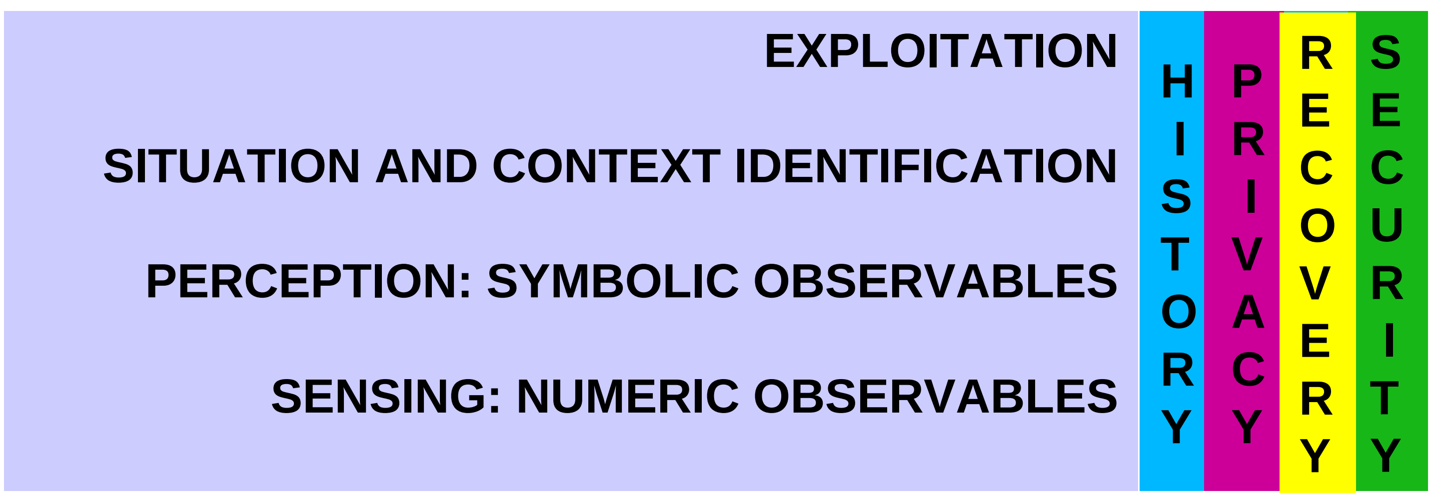
Conceptual CM (Coutaz, Crowley, Dobson, Garlan)

- Contexts are represented as sets of entities (e.g. objects, values, persons), roles for these entities (objects' functions, peoples' current roles), relations between entities, situations.
- The possible contexts for a scenario constitute an information space modeled as a directed state graph, where each node represents a context and edges denote the conditions for changing context

entity Bob at the cafè plays the role of an architect while at the train station he is a traveller; entity "lump of sugar" plays the role of a building while Bob shows it to Jane on the table

Conceptual CM
(Coutaz, Crowley, Dobson, Garlan)

- A runtime infrastructure is a middleware that instantiates entities, roles and relations for the current state of a context, with different levels of abstraction, by allowing the collection of all the information required to identify current context values and predict changes in the situation or in the actual context.



Conceptual CM (Coutaz, Crowley, Dobson, Garlan)

- A *context* is a composition of *situations* that concerns a set of *roles* and *relations*
- A context determines the configuration of processes necessary to detect and observe the entities that can play the roles and the relations between roles that must be observed

Context → {Role_1, Role_2,…,Role_n; Relation_1,…,Relation_m}

- A situation is a kind of state, defined by a conjunction of relations
- Relations are predicate functions evaluated over the properties of the entities that have been assigned to roles
- A change in the assignment of an entity to a role does not change the situation, unless a relation changes in value

Conceptual CM (Coutaz, Crowley, Dobson, Garlan)

- Entities are assigned to roles by role assignment processes. The context model specifies which roles are to be assigned and launches the necessary role assignment processes
- A meta-supervisor determines what kind of entities can play each role, and launches processes to detect and observe these entities. The most suitable entities are assigned to the roles
- Relations are evaluated, and the set of relations determines the situation
- The relations in the situation are computed on the entities assigned to roles. Situation changes when the relations between entities change.
- If the assignment of entities to situations changes, the situation remains the same. However, the system may need to act in response to a change in role assignment.

if the person playing the role of speaker changes, then a video communication system may need to change the camera view to center on the new speaker.

Conceptual CM (Coutaz, Crowley, Dobson, Garlan)

Conclusions:

- A context is a network of situations concerning a set of roles and relations.
- Roles are services or functions relative to a task.
- Roles may be “played” by one or more entities.
- A relation is a predicate defined over the properties of entities.
- A situation is a configuration of relations between the entities.

Observations are provided by perceptual processes defined by a tracking process or transformation controlled by reflexive supervisor. Perceptual processes are invoked and organized into hierarchical federations by reflexive meta-supervisors. A model of the user’s context makes it possible for a system to provide services with little or no user intervention

Context models in computer science

- The **QUALEG** european project aims at providing local governments with an effective tool for bi-directional communication with citizens.
- ontologies are considered as a result of a manual effort of modeling a domain, while contexts are *system generated models*
- proposes a unique combination of a global ontology with a dynamic context, for dynamically adapting eGovernment IT tools to a multi-lingual and multi-cultural setting

→**QUALEG** *aims at adapting information to the user's needs*

Mapping Context and Ontologies (A. Segev and A. Gal)

- Aimed at supporting evolving organizations, dynamically adapting to the needs of the citizens
- Context is a lightweight, textbased mechanism that defines the essence of an ontological concept: a *context* is a set of words defining a document, possibly associated with weights that represent the relevance of a word to a document
- A context can be modified to adapt to changes over time in the focus of a government following external changes, or citizen requests. It can also serve in defining minor changes in perspectives between local governments.
- Once changes are accumulated, an ontological change may be needed, representing a major shift in policy, to be captured by redesigning the ontology itself.

Mapping Context and Ontologies (A. Segev and A. Gal)

- Each concept in the ontology is represented by a name and a context.
- contexts serve as the *local interpretation* of the global ontology, which can be maintained by a user without the involvement of the IT personnel
- context can serve as the "translation" mechanism, in which ontological concepts are interpreted in the local language
- context can serve as a compensating element in ontologies, adding topics of interest to the global ontology
- The model also handles the uncertainty associated with automatic context extraction from existing documents
- ontology concepts are ranked according to their suitability to a given context

Context models in computer science

CoBrA is an agent-based Context Broker Architecture, whose goal is to provide a shared context model for event/meeting management

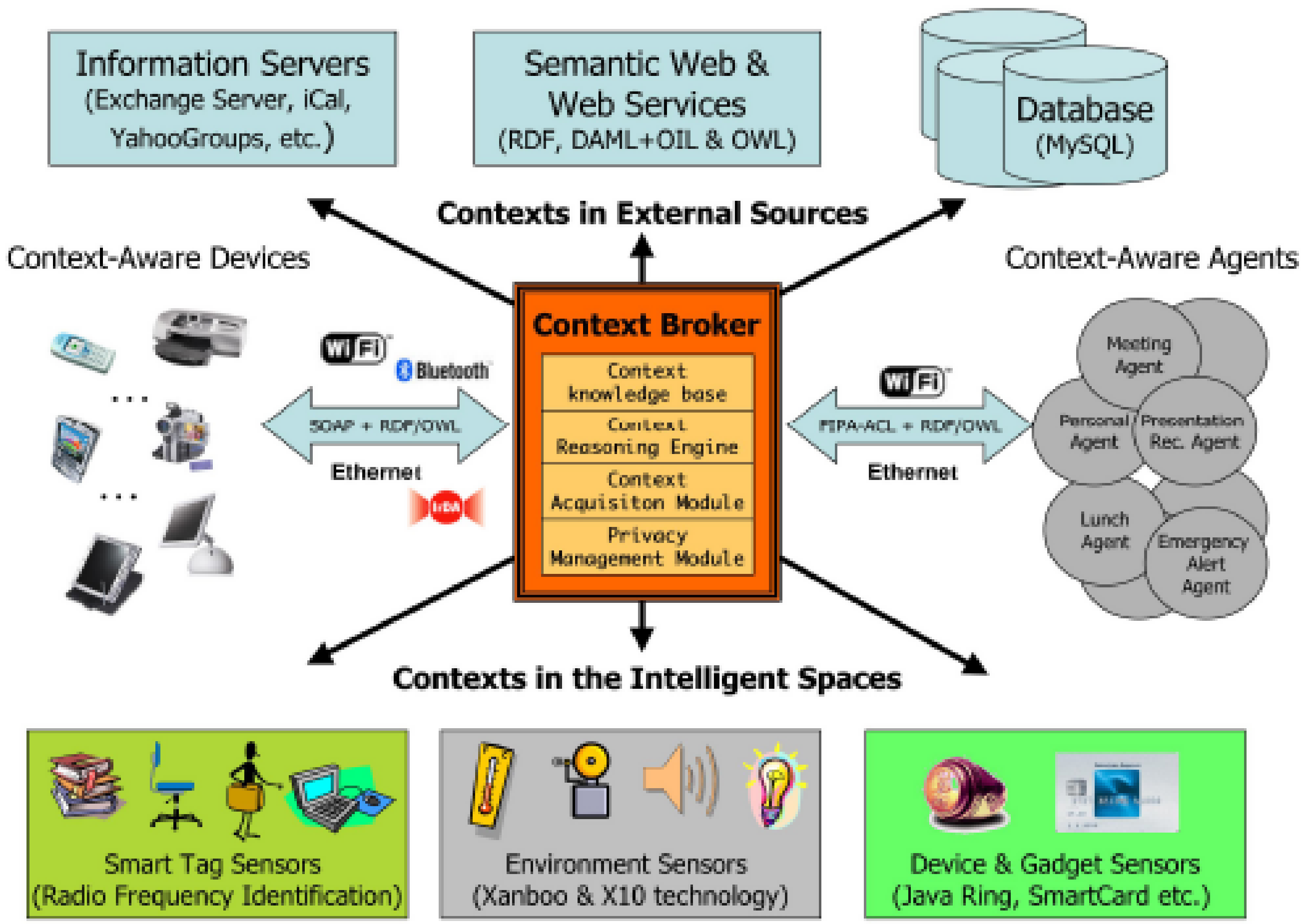
- Based on ontologies (Context Knowledge Base)
- Context built by a distributed effort (rules describing how shared context is built)
- It takes into account privacy issues
- Presence of a *context broker*
- detecting inconsistent beliefs about certain contexts
- Limited flexibility (mono-target context model)

→ *CoBrA models agreement and sharing*

CoBrA
(Chen, Finin, Joshi)

- **An agent based architecture for supporting** *context-aware computing in intelligent spaces*
- *Intelligent spaces* **are physical spaces (e.g., living rooms, vehicles, corporate offices and meeting rooms) populated with intelligent systems**
- *Intelligent context broker* **maintains and manages a shared contextual model on the behalf of a community of agents. It can be federated with other context brokers**
- **agents can be**
  - *applications* **hosted by mobile devices that a user carries or wears (e.g., cell phones, PDAs and headphones)**
  - *services* **that are provided by devices in a room (e.g., projector service, light controller and room temperature controller)**
  - *web services* **that provide a web presence for people, places and things in the physical world (e.g., keeping track of people's and objects' whereabouts)**

CoBrA
(Chen, Finin, Joshi)



CoBrA

(Chen, Finin, Joshi)

A *context broker* **has four main functional components:**

1. *Context Knowledge Base:* **a persistent store for context knowledge in an intelligent space. This knowledge base provides a set of API's for other components to assert, delete, modify, and query stored knowledge.**
2. *Context Reasoning Engine:* **a reactive inference engine that reasons over the knowledge base. Its main function is to deduce additional knowledge from information acquired from external sources and to maintain the consistency of the knowledge base.**
3. *Context Acquisition Module:* **a collection of predefined procedures for acquiring information from the external sources. It serves as a middleware abstraction for acquiring contexts from heterogeneous sources (e.g., physical sensors, web services, databases, devices and agents).**
4. *Privacy Management Module:* **a set of communication protocols and behavior rules that the broker follows when performing privacy management tasks (i.e., negotiate privacy policies with new users and enforcing these policies when sharing information with agents in the community).**

CoBrA - Intelligent Meeting Room Scenario

1. R210 is an intelligent meeting room equipped with RFID sensors. As Alice enters the room, sensors inform the R210 broker that a cell phone belonging to her is present and the broker adds this fact in its knowledge base.
2. the agent on Alice's Bluetooth enabled cell phone discovers R210's broker and engages in a "hand shake" protocol (e.g. authenticates agent identities and establishes trust) after which it informs the broker of Alice's privacy policy.
3. Based on the policy, the broker (i) acquires and reasons about Alice's location and activity contexts, (ii) informs Alice's personal agent at home when Alice's contexts change, and (iii) shares her contexts with agents in the meeting room.

CoBrA - Intelligent Meeting Room Scenario

4. Knowing Alice's cell phone is currently in R210, the broker concludes Alice is also there. R210 is a part of the Engineering building, These conclusions are asserted into the broker's knowledge base.
5. the broker informs Alice's personal agent of her whereabouts. Personal agent attempts to determine why Alice is there. Her Outlook calendar has an entry indicating that she is to give a presentation on Campus about now.
6. the personal agent concludes that Alice is in R210 to give her talk and informs the R210 broker.Broker shares this information with the projector agent and the lighting control agent in the ECS 210. Projector agent downloads the slides from Alice's personal agent and sets up the projector, the lighting control agent dims the room lights.

CoBrA (Chen, Finin, Joshi)

CoBrA Ontology Classes		CoBrA Ontology Properties	
"Place" Related	Agents' Location Context	"Place" Related	Agent's Location Context
Place AtomicPlace CompoundPlace Campus Building AtomicPlaceInBuilding AtomicPlaceNotInBuilding Room Hallway Stairway OtherPlaceInBuilding Restroom Gender LadiesRoom MensRoom ParkingLot	ThingInBuilding SoftwareAgentInBuilding PersonInBuilding ThingNotInBuilding SoftwareAgentNotInBuilding PersonNotInBuilding ThingInRoom SoftwareAgentInRoom PersonInRoom	latitude longitude hasPrettyName isSpatiallySubsumedBy spatiallySubsumes accessRestricted- ToGender lotNumber	locatedIn locatedInAtomicPlace locatedInRoom locatedInRestroom locatedInParkingLot locatedinCompoundPlace locatedInBuilding locatedInCampus
"Agent" Related	Agent's Activity Context	"Agent" Related	Agent's Activity Context
Agent Person SoftwareAgent Role SpeakerRole AudienceRole IntentionalAction ActionFoundInPresntation	PresentationSchedule EventHappeningNow PresentationHappeningNow RoomHasPresentationHappeningNow ParticipantOfPresentation- HappeningNow SpeakerOfPresentationHappeningNow AudienceOfPresentationHappeningNow PersonFillsRoleInPresentation PersonFillsSpeakerRole PersonFillsAudienceRole	hasContactInformation hasFullName hasEmail hasHomePage hasAgentAddress fillsRole isFilledBy intendsToPerform desiresSomeone- ToAchieve	participatesIn startTime endTime location hasEventHappeningNow invitedSpeaker expectedAudience presentationTitle presentationAbstract presentation eventDescription eventSchedule

Context models in computer science

ACTIVITY : approach based on Activity Theory, which allows the description of key aspects influencing human activity.

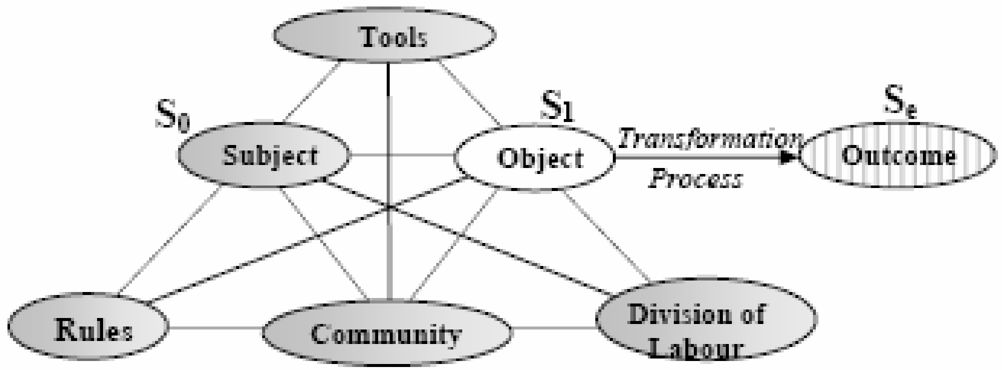
- the notion of context is intended as the set of elements which have some influence on users' intentions while performing an activity.
- model focused on the categories of user, community and the rules needed to relate a user to his/her community;
- each category can be represented by a tree-based structure, where lower levels of the tree represent more detailed information about the context category that can be used for reasoning about upper levels.
- no formal description of the context model

→ACTIVITY models the problem as a whole, but is a little more focused on agreement and sharing

Activity theory
(Kaenampornpan and O'Neill)

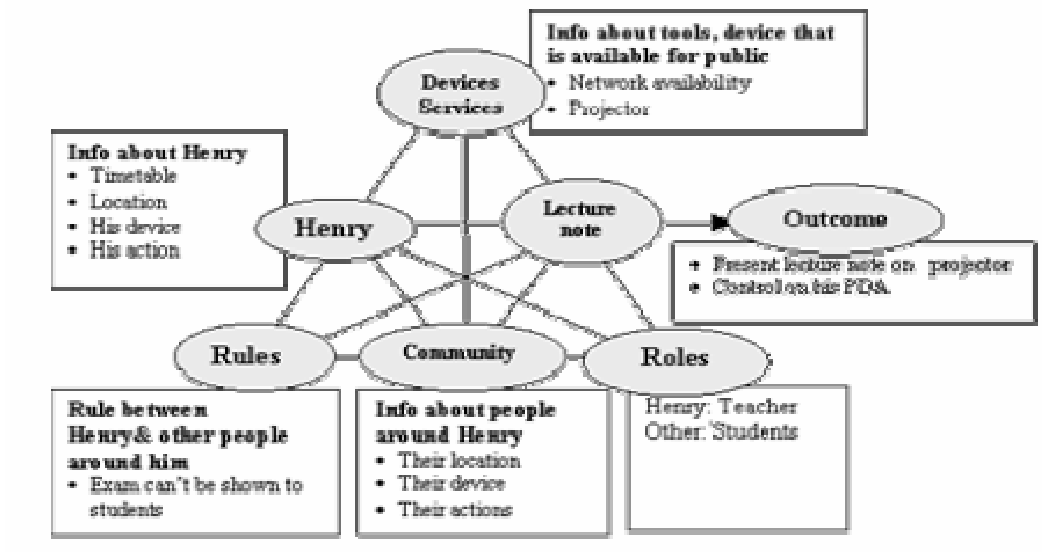
- Humans cannot fully understand the full moment-to-moment richness of other humans' activities, states, goals and intentions, yet *they interact in many highly contextualized ways*
- Context represented by means of a model of the influences on users' activities
- Activity Theory uses a simple standard form to represent concepts such as roles, rules and tools, which have important impacts on users' activities
- Activity Theory also maps the relationships amongst the elements that it identifies as having an influence on human activity

Activity theory
(Kaenampornpan and O'Neill)



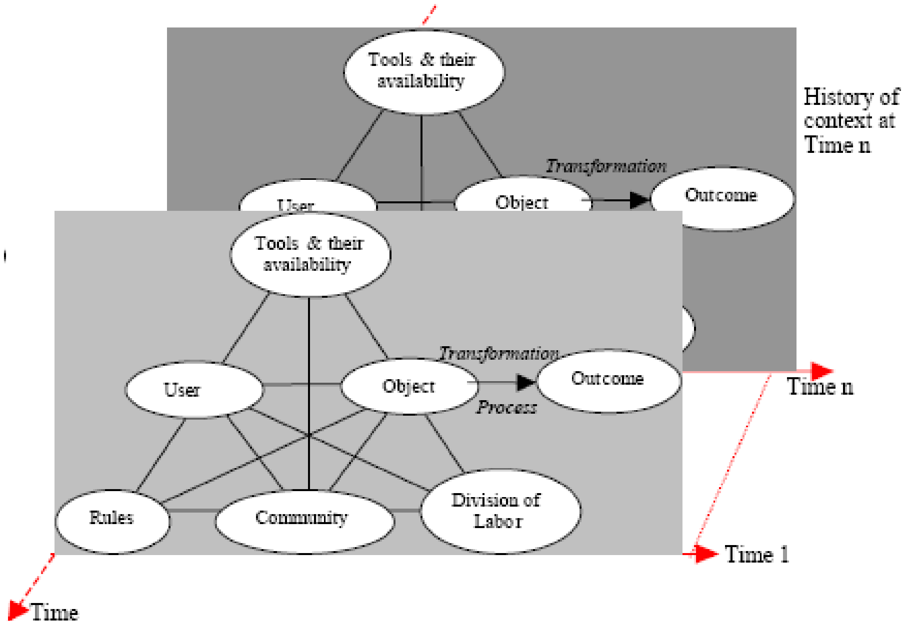
- Original Triangular Structure of Human Activity introduced by Engeström (1999)
- Activity Theory captures information about the current situation, (S0) and the outcome (Se) once the activity is performed, but does not provide an adequate account of a user's current object or intention (S1)
- Time is a crucially important part of context. This includes not just current time, but also past time (that contributes a history element to the context) and future time (that allows for prediction of users' actions from the current context).

Activity theory
(Kaenampornpan and O'Neill)



- Henry is a PhD student. He is assigned to teach once a week on Tuesday 9.15-10.15am. On Tuesday at 9.15, he arrives at the teaching room
- The context-aware system presents a selection of files on his PDA based on his current location, time, people around him, his role, rules and tool availability
- Once he has selected a file, the system presents the contents on a projector for the students to see and allows Henry to control it via his PDA.

Activity theory
(Kaenampornpan and O'Neill)



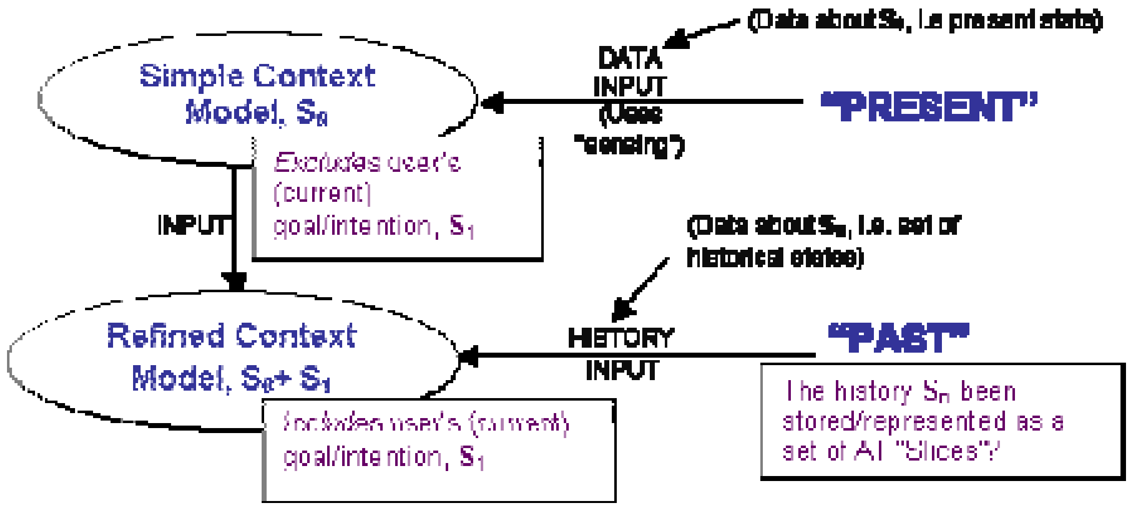
- History is modelled as a set of states in the past
- Each past state is represented as an Activity Theory model, which captures the context of past activities
- This information includes the initial state (**S0**), intention (**S1**) and outcome (**Se**) of the activity

Activity: elements of the model (Kaenampornpan and O'Neill)

- *User:* **Information about the user and her physical environment that has influence on her activity, including user's** *current location, action, device* **and** *timetable***.**
- *Tools and their availability:* **Tools that are available in the public space and their availability, including** *device characteristics, public services* **and** *computing environment* **such as network availability.**
- *Rules:* **Norms, social rules and legislation within which the user relates to others in her community.**
- *Community:* **Information about people around the user (in both physical and virtual environments) that may have an influence on her activity.**
- *Division of Labor:* **Roles of user in that situation including who can perform which tasks on the object.**
- *Object:* **User's intention and objective. The system uses all the elements above to decide about the user's intention or objective.**
- *Time:* **the occurrence of events in the past, the present and the future.**

NOTE: *EACH OF THESE CATEGORIES IS FURTHER ANALYZED AT ANY NUMBER OF LEVELS, THE LOWEST LEVEL BEING THAT OF THE SPECIFIC CHARACTERISTICS IN THE CURRENT SCENARIO*

Activity theory
(Kaenampornpan and O'Neill)



1. Collect information on each element in the Activity Theory model, e.g. from sensors or databases. Here the Activity Theory model is used as a guide for the designers to what types of information must be taken into account.
2. This information is used to model the context of the user's current activity (S0). This does not include the user's intention or goal (S1), as such information cannot be sensed
3. The context model references the history, which records the user's context in achieving his/her goals in the past, in order to infer the user's current goal
4. Output: a refined context model that includes an understanding of the user's goal or Object (in Activity Theory terms)

Context models in computer science

CoDaMoS (Context-Driven Adaptation of Mobile Services) offers a rather sophisticated context model

- **Represented as a complex ontology.**
- **The system provides a context reasoning service, based on user defined rules, and a context source discovery service**
- **No constraints to limit the number of admissible contexts**
- **Context represented by an extensible structure based on 4 categories:** *user*, *environment, service (in CoDaMoS)* **and** *platform*
- **A point in the multidimensional context space is represented as a graph of concept instances – high representation complexity**

→ *CoDaMoS models the problem as a whole, but are a little more focused on channel, device and location*

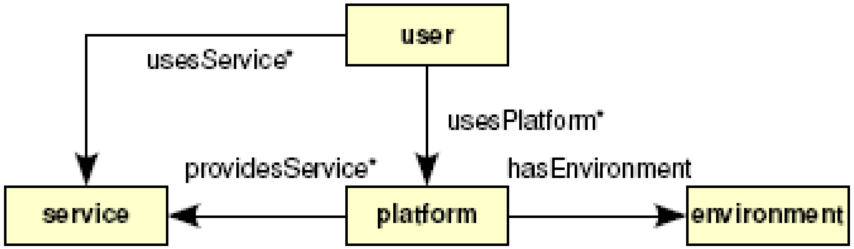
CoDaMoS

(Preuveneers, Van den Bergh2 et al.)

- The context model is an adaptable and extensible ontology for creating context-aware computing infrastructures, from small embedded devices to high-end service platforms
- It describes all the relevant information to allow software on a device to semi-automatically interact with its environment
- CoDaMoS requirements:
  - Application adaptivity
  - Resource awareness
  - Mobile services
  - Semantic service discovery
  - Code generation
  - Context-aware user interfaces

CoDaMoS
(Preuveneers, Van den Bergh2 et al.)

Context ontology overview



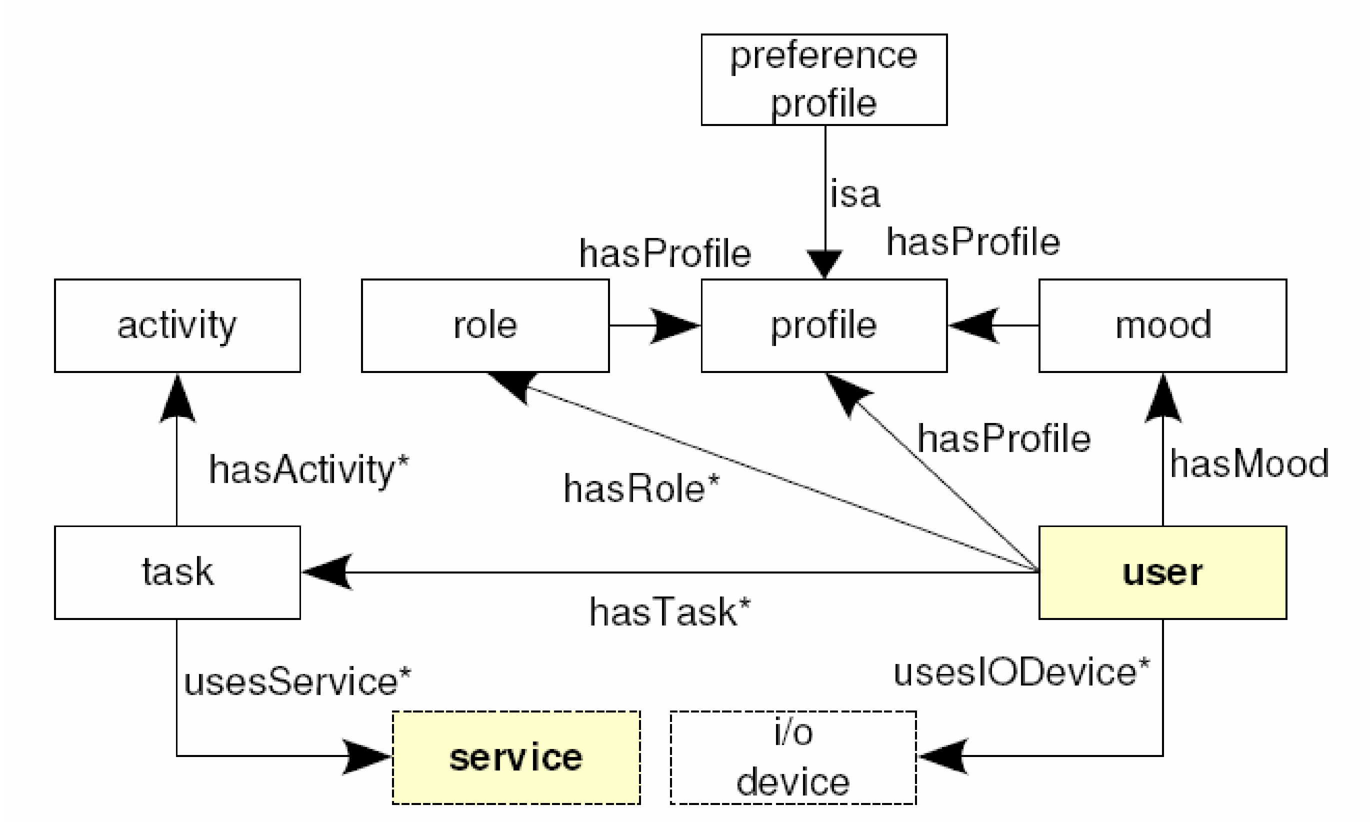
Every device will contain its own context specification with a full description of its provided services, plus pointers to relevant information on the devices in its environment

Four main entities constitute the (extensible) ontology:

- **User:** **plays an important role within Ambient Intelligence. The appliances within its environment should adapt to the user, and not vice versa. Important properties include a user's profile, but also his preferences, mood and current activity**
- **Environment:** **time and location information, and environmental conditions, such as temperature and lighting**
- **Platform:** **hardware and software description of a specific device. This includes among other things specifications of the processor, available memory and bandwidth, information about the operating system and other available software libraries**
- **Service:** **specifying semantic and syntactic information sustains easy service discovery and service interaction using a well-defined service interface**

CoDaMoS

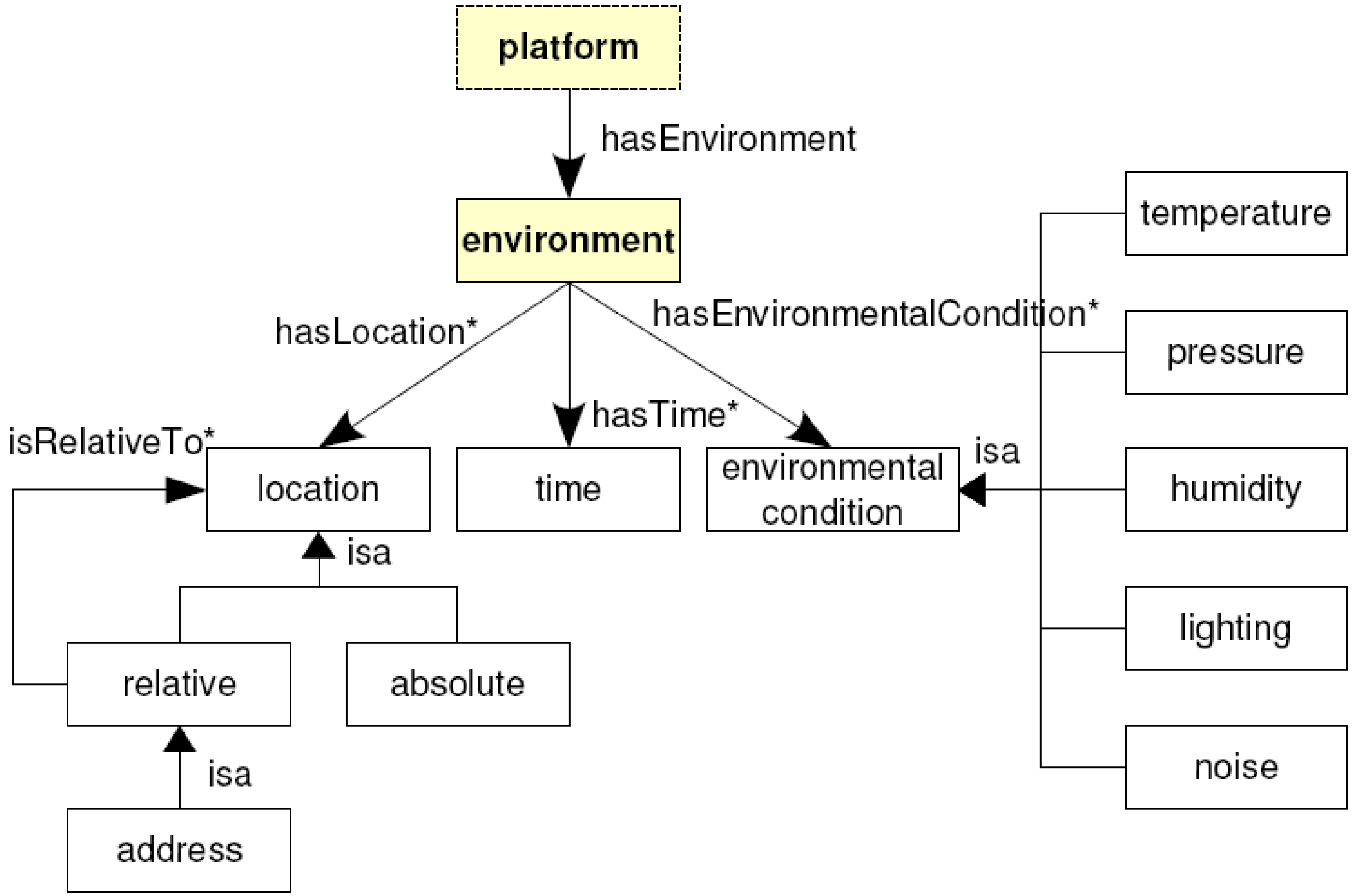
(Preuveneers, Van den Bergh2 et al.)



User ontology

CoDaMoS

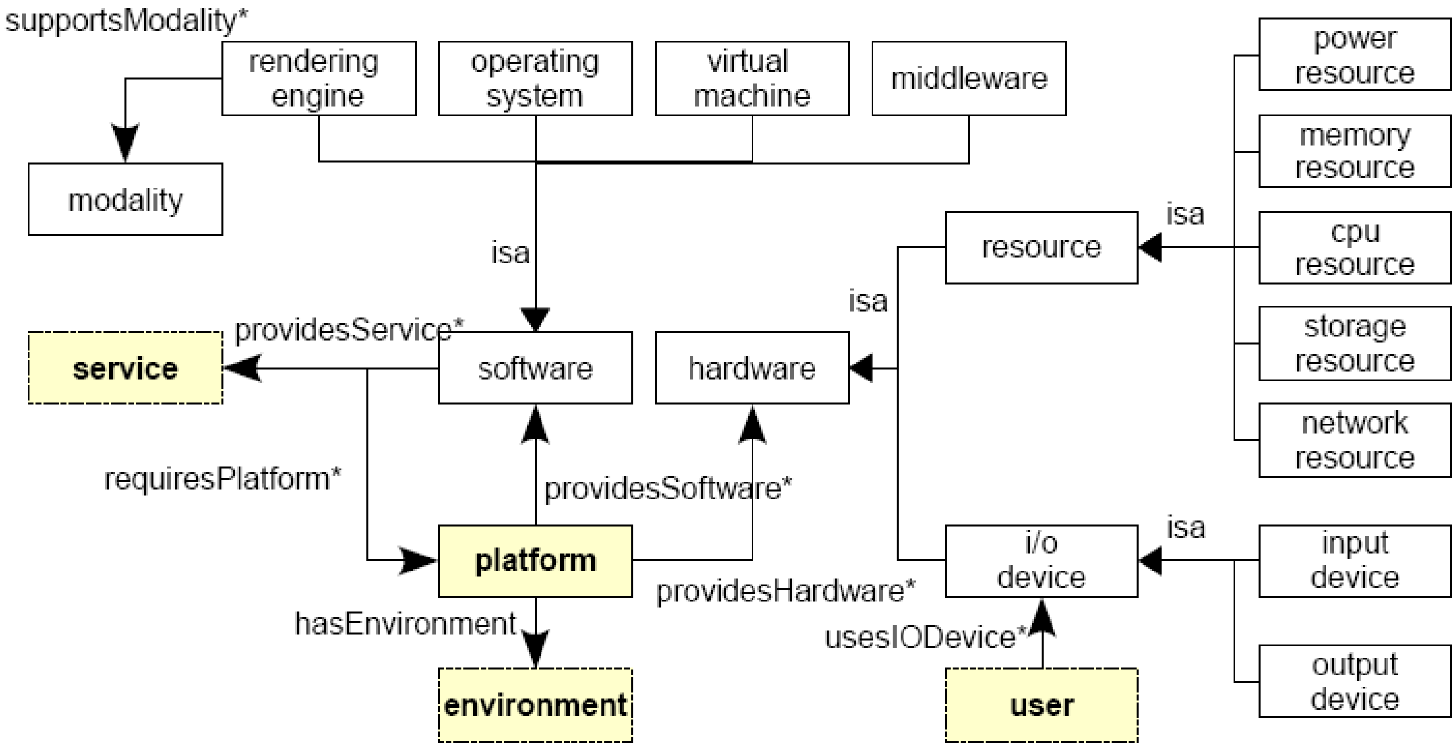
(Preuveneers, Van den Bergh2 et al.)



Environment ontology

CoDaMoS

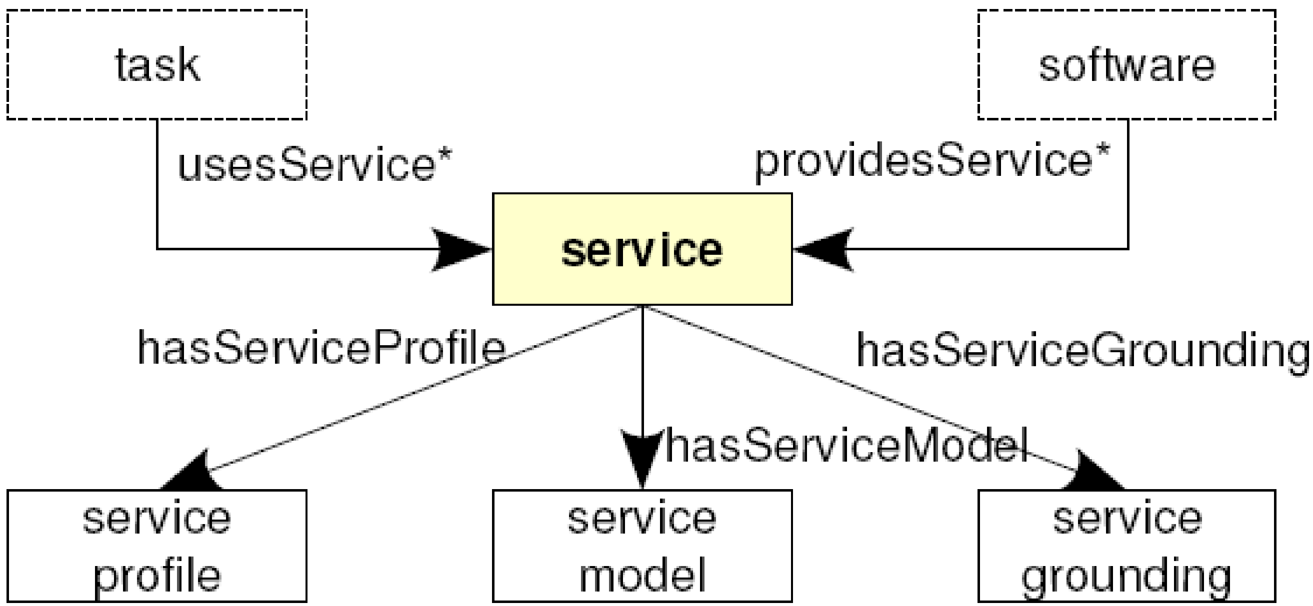
(Preuveneers, Van den Bergh2 et al.)



Platform ontology

CoDaMoS

(Preuveneers, Van den Bergh2 et al.)



Service ontology

CoDaMoS

(Preuveneers, Van den Bergh2 et al.)

Context storage components:

- Context representation
- History of context
- Outdated and redundant info management
- Context repository
- Adaptation support

Context manipulation components:

- Context transformation
- Context reasoning
- Context-based decision making and adaptation
- Component-based context manipulation
- Support for adaptation

Context models in computer science

- **CC/PP** (Composite Capabilities/Preference Profiles) (W3C recommendation)
- A CC/PP profile is a description of device capabilities and user preferences that can be used to guide the adaptation of content presented to that device.
- Profile refers to the document(s) exchanged between devices that describe the capabilities of a device
- Objective: delivering content that is tailored to the capabilities of different devices.
- Based on RDF, a natural choice since user agent profiles are metadata intended primarily for communication between user agents and resource data providers

→ *CC/PP models the context as a matter of channel-device-presentation*

CC/PP (W3C)

- A CC/PP profile:
  - contains CC/PP attribute names and associated values that are used by a server to determine the most appropriate form of a resource to deliver to a client
  - is structured to allow a client to describe its capabilities by reference to a standard profile, accessible to an origin server or other sender of resource data, and a smaller set of features that are in addition to or different than the standard profile
- A set of CC/PP attribute names, permissible values and associated meanings constitute a *CC/PP vocabulary*
- CC/PP is intended to be used in conjunction with adequate trust and security mechanisms

Context models in computer science

CSCP is a Mobility Portal combining application-spanning media conversion and transcoding with application-specific information filtering

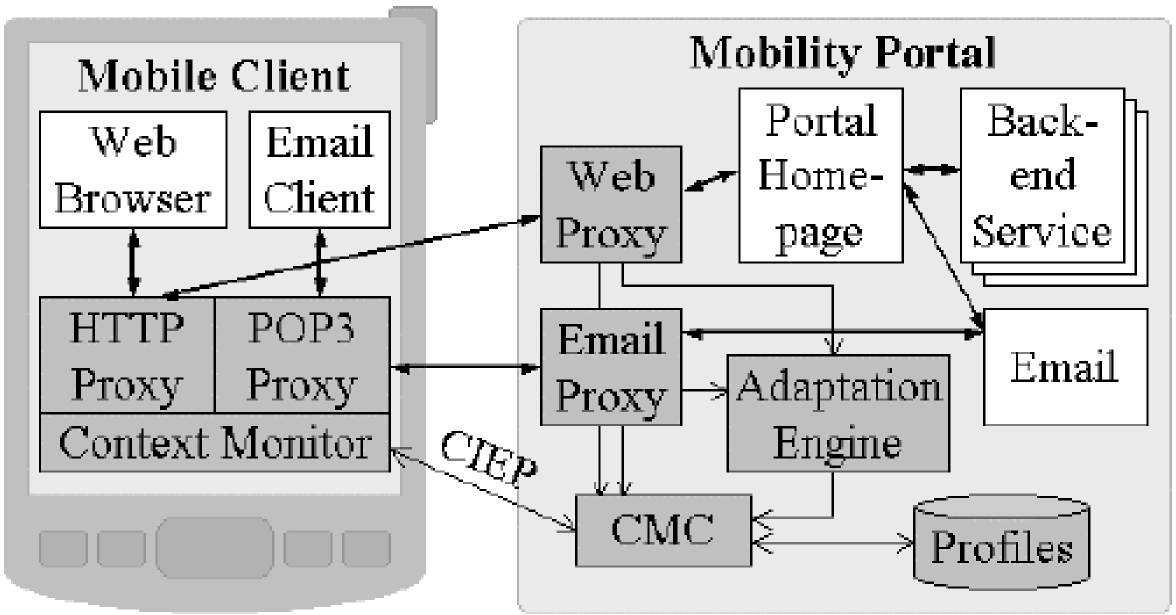
- Structured to describe the entire context of mobile sessions
- Adapts to user channel, device and profile features
- Context model based on RDF, thus fully flexible
- One instantiation of the model represents a single context

→CSCP models the context as a matter of channel-device-presentation

CSCP
(Buchholz, Hamann, Hubsch)

- **context information comprise**
  - the capabilities of the client device
  - transmission characteristics of the network connection
  - user specific information, including *viewing and filtering preferences*, *topics of interests*, *authentication information*, *subscriber information*
- **extensible to reflect further aspects like environmental information (e.g. location, noise level)**
- **w.r.t. CC/PP, CSCP provides:**
  - a more powerful structuring capability
  - context-sensitive interpretation of attributes requiring globally unambiguous attribute naming

CSCP
(Buchholz, Hamann, Hubsch)



CSCP Mobility Portal

CSCP (Buchholz, Hamann, Hubsch)

- The CMC is the central entity for context management
- Context monitor performs initial setup of a context profile on the mobile device
- Context profile is transferred to the CMC using an HTTP-based protocol called Context Information Exchange Protocol (CIEP)
- CIEP is a session protocol defining primitives for session setup i(user authentication and transfer of the initial context profile, context profile updates, and session shutdown)
- CMC stores the context profile in a local profile repository and assigns a Mobile Session Identifier (MSID) with the associated CIEP session
- CIEP sessions are long lived and may span multiple application sessions

CSCP
(Buchholz, Hamann, Hubsch)

- CSCP does not impose any fixed hierarchy to express natural structures of context information
- Attribute names are interpreted context-sensitively according to their position in the profile structure. Thus, unambiguous attribute naming throughout the profile is not required
- A profile describes all context information relevant to a client's mobile session, and may contain references to external resources, such as device defaults which can be retrieved from the device vendor's web site
- CSCP allows to merge profile subtrees with their corresponding default subtrees and thus allows for complex profile structures

Context models in computer science

COMANTO proposes a hybrid context modeling approach to handle context objects and context knowledge.

- Context objects: location-based context model considering fixed (e.g., regions, streets, etc.) and mobile location data (e.g., people, vehicles).
- Context knowledge: general COMANTO ontology as a public context semantic vocabulary
- Efficient reasoning on contextual concepts (such as users, activities, tools…) and associations
- The ontology is not domain- or application-oriented
- Middleware infrastructure to acquire, store, and manage context information of the COMANTO ontology
- General purpose
- Very expressive formal model
- No possibility to discard useless contexts

→ *COMANTO models location as well as user activity aspects*

Context models in computer science

FAWIS is focused on Web-based Information Systems

- Presentation and navigation adjustment based on the notion of user profile – context is a set of profiles
- Rules to associate contexts/profiles to system configurations
- Flexible: it can be used to represent a variety of contexts
- Variable granularity: at different levels of details
- No expression of constraints

→ FAWIS models the context mainly as channel-device-presentation,

→ due to its flexibility it can also be considered as a tool for data tailoring

Context models in computer science

MAIS is a Multi Channel Adaptive Information System

- meant to adapt the interaction and provide information and services according to changing requirements, execution contexts, and user needs.
- objective of configuring the software on board of the device based on:
  - presentation,
  - device characteristics
  - available channel

→MAIS models the context as a matter of channel-device-presentation

Context models in computer science

EXPDOC's target is to support experiential systems

- **Based on semantic networks**
- **Integrates WordNet to define the relationships between several semantic networks used to capture different aspects of the context**
- **To provide an enriched learning environment**
- **Additional, related, but not required information - "serendipitous" activities (1)**
- **Opposite goal w.r.t data tailoring: here context used to augment the information at the user's disposal**

→ *EXPDOC models user activity aspects*

(1) *serendipity*: **faculty or phenomenon of finding valuable or agreeable things not sought for**

Context models in computer science

SCOPES: **in a P2P collaborative environment, assertions are exchanged among peers to enable P2P data interoperability**

- **Based on the concept of mutual belief**
- **Mappings created among source schemata**
- **Notion of evolving context**
- **It is not possible to define a context model independent of the data sources**
- **It does not include constructs to represent location or user profile.**

→ SCOPES models agreement and sharing

Context models in computer science

CR is a Context-Relational model which extends the relational model to deal with context

- Based on the relational model
- Entities have different *facets,* one for each possible context
- Resembles temporal databases, or versioning (based on possible worlds)
- A number of relational operators defined for multi-facet entities

→CR is mainly a tool for information reshaping (different from tailoring)

Context models in computer science

U-Learn is focused on the support of learning

- Learner and learning content described by two ontologies
- A rule-based system provides a content-to-learner matching mechanism
- The content can be either a service or a set of data.
- Data can be enriched by adding content metadata, the user's context described by the learner ontology and the matching can be used to select the relevant data depending on the context
- Formalization not complete yet
- (perhaps) support for sensor integration

→ *U-Learn models data and service tailoring*

Context models in computer science

CASS is a centralized server-based context management framework, meant for small portable devices

- High-level abstraction on context sensed by appropriate distributed sensors
- It manages both time and space, taking into account the context history
- It provides context reasoning
- No user profiling capabilities.

→ *CASS models location and environment aspects*

Context models in computer science

HIPS/HyperAudio **supports an automatic context-aware museum**

- **Attention on spatio-temporal issues of the context,**
- **Guess the current user activity from information about user spatio-temporal coordinates**
- **Limited flexibility (mono-target context model)**

→ *HIPS/HyperAudio models location and environment, together with user activity aspects*

Context model features and systems exposing them

System	Space	Time	Space/Time coordinates (**R**elative or **A**bsolute)	Context history	Subject (**U**ser or **A**pplication)	User profile (**R**ole or **F**eatures based)	Variable context granularity	Valid context constraints	Type of formalism: Key-value-based	Type of formalism: Mark-up based	Type of formalism: Logic-based	Type of formalism: Graph-based	Type of formalism: Ontology-based	Formality level (**H**igh or **L**ow)	Flexibility	Context construction (**D**istributed or **C**entralized)	Context reasoning	Context quality monitoring	Ambiguity/Incompleteness mgmt.	Automatic learning features	Multi-context model
ACTIVITY	+		A	+	U	F	+					+		L	+	C	+				+
CASS	+	+		+	U						+			L		D	+				
CoBrA	+	+	A		A	F							+	H	+	D	+		+	+	
CoDaMoS	+	+	R/A		A	F							+	H	+	D	+	+			
COMANTO	+	+	R/A		A	F							+	H	+	D	+				
Context-ADDICT	+	+	R/A		A	R	+	+		+		+	+	H	+	C					
Conceptual-CM	+	+	R	+	A	R						+		L	+	C	+		+	+	+
CSCP					A	F				+				L		C					+
EXPDOC		+	R	+	U	F					+	+		H		C				+	
FAWIS				+	U	F	+		+					H		C			+	+	+
Graphical-CM	+	+	R		A	F						+		H	+	C		+	+		+
HIPS/HyperAudio	+	+	A	+	U	F			+					L		C	+		+	+	
MAIS	+	+	A		A	F	+						+	H		C					
SCOPES					A						+			H		D	+		+		+
SOCAM	+	+	R/A		A	F							+	H	+	D	+	+			
U-Learn	+	+	A		U	F		+					+	H	+	D					+

Conclusion on context models in computer science

Due to the complexity of the problem as a whole and to the multitude of different applications, the best models *have a well defined focus*, **and try to support only** *one of the above mentioned context-modeling categories*

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