

Master IA2S

# Ambient Intelligence-AAL (Ambient-Assisted Living) : principes et challenges

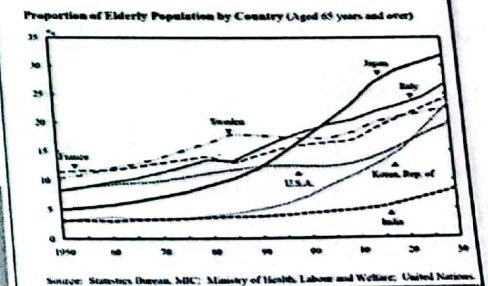
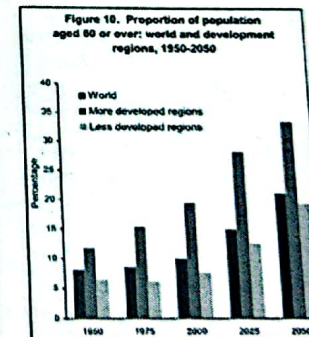
## Outline

- Introduction
- Perception and Actuation Technologies
- Context recognition
- Use Case: Ambient Cognitive assistance

## Introduction

## Social, economic and industrial issues

- United Nations statistics: In most industrialized countries, the number of elderly is continuously increasing.
- By 2050, 1 in 5 person in the world will be age 60 or older (France -10 M of people aged 60 years and over)



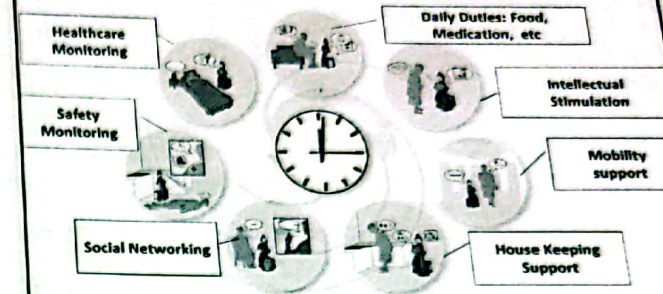
UN Report, Department of Economic and Social Affairs, Population Division, 2001  
<http://www.un.org/esa/population/publications/worldageing19502050/>

### Consequences & perspectives

- An increase in age-related disease
- Rising healthcare costs
  - By 2040: Alzheimer related costs in USA will be 2 trillion dollars
- Shortage of professionals
  - Nurses shortage: 120,000 and 159,300 doctors by 2025
- Increase in number of individuals unable to live independently
  - Facilities cannot handle coming "age wave"
- Towards silver Economy: a new economic and industrial sector-Healthcare and well-being services and products

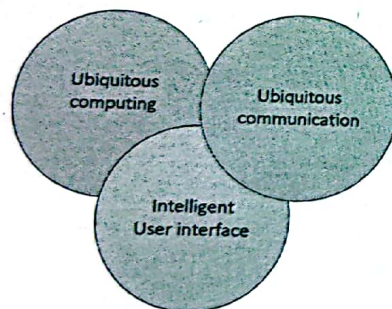


### Older Adults Needs



### Ambient Intelligence-human centric technology

- Aml refers to a new paradigm in information technology, in which people are empowered through a cyber-physical environment that is aware of their presence and context and is sensitive, adaptive and responsive to their needs, habits, gestures and emotions.

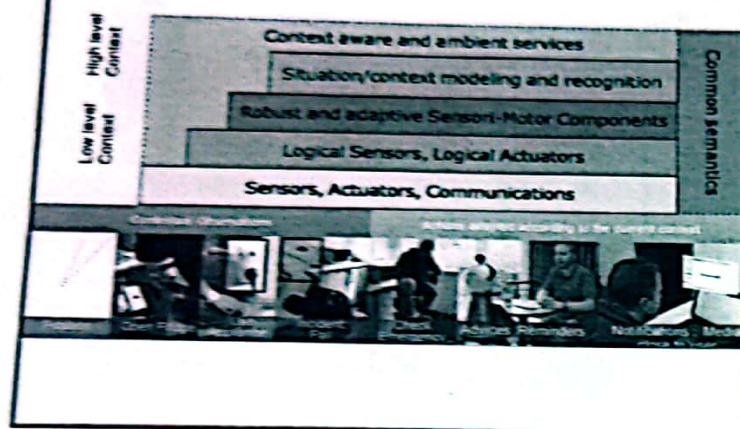


### Context and context- awareness

- **Definition of context (A.K. Day)** : Context is any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves.
- **Definition of context-awareness (A.K. Day)** A system is context-aware if it uses context to provide relevant information and/or services to the user, where relevancy depends on the user's task.



## Topics & Challenges



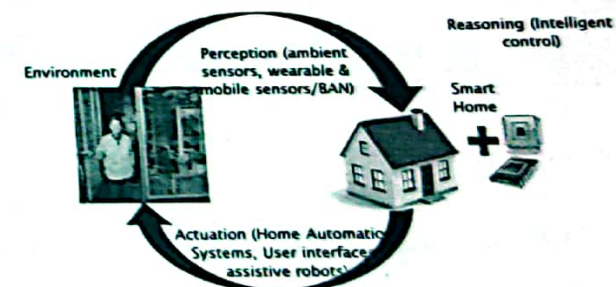
## Main issues

- **Perception, actuation and HCI technologies**
  - less intrusive,
  - large volumes of multidimensional data
  - more natural HCI
- **Interoperability**
  - Data Level
  - Knowledge level
- **Context management**
  - Interpretation and recognition of context and activity
  - mobility tracking,
  - context awareness
- **Reliability**
- **Privacy and security**

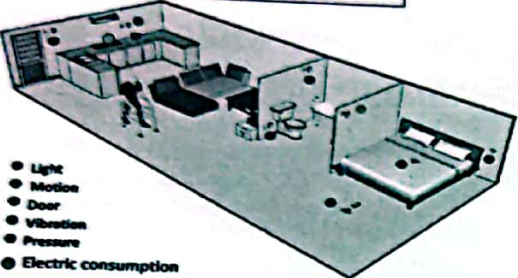
## Perception and actuation technologies

## Ambient living technologies- Smart homes

- Sensors & actuators integrated into everyday objects
- A set of services having three functions: perception-actuation-control
- Knowledge acquisition about inhabitant



### Smart Home Sensors- perception through Ambient sensors


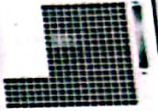


- Light
- Motion
- Door
- Vibration
- Pressure
- Electric consumption

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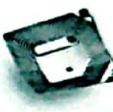


### Smart Home Sensors- perception through Ambient sensors

- PIR (Passive Infrared Sensor)
- RFID
- Pressure sensors (in beds, floor)
- Contact switch sensors
- Camera (Kinect)
- Microphone
- ...

A) A photo of the floor      B) Floor Sensor Data

Floor Pressure Sensor.







PIR      RFID      Kinect      Leap Motion


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### Perception through Wearable & Mobile Sensors


- Applications
  - Health monitoring
  - Navigation and stray prevention
  - Mobile persuasive technologies





Smart Cane, UCLA, 2008



LifeShirt By Vivometrics®



Samsung Galaxy Gear

after integration onto skin → after deformation

Epidermal Electronics, 2013

### Measurements & Sensors

#### Movement

- Accelerometer
- Gyroscope

#### Biochemical

- Stress markers (lactate in sweat)
- Wound healing (pH and infection markers)

#### Vital Signs

- Respiration sensors
- Thermal sensors
- Galvanic skin response (GSR) sensors
- Cardiac Activity
  - Pulse oximeter
  - ECG devices
  - Doppler radars

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### Wearable robots for physical assistance: exoskeletons



Robot Hal 5 (Cyberdyne-Japan)



EICOSI: Exosquelette Intelligent Communicant Sensible à l'Intention  
LISN (UPMC - France)

### Data Transfer

- Wireless standards
  - Wifi (IEEE 802.11), Bluetooth (IEEE 802.15.1), ZigBee (IEEE 802.15.4), 6LowPan
- Automation and control networks: Lonworks, BACnet, KNX, etc.
- Many standards include IP as part of their specification to ease the process to connect things to the Internet.
  - This is not enough to ensure interoperability at required IoT application level. Efficient data transmission mechanisms: CoAP, DPWS, XMPP, RESTful HTTP, and MQTT.

### HCI technologies:

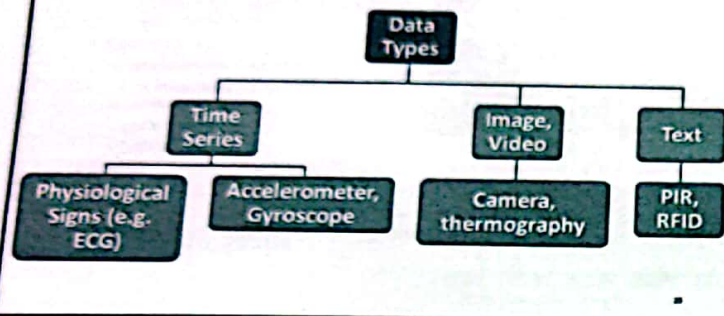
- Classical user interfaces: tablets, smartphones, smart TV, etc.
- Natural user interfaces:
  - Speech, gesture, body motion tracking, emotions, facial expressions, attention, etc.

### Context recognition



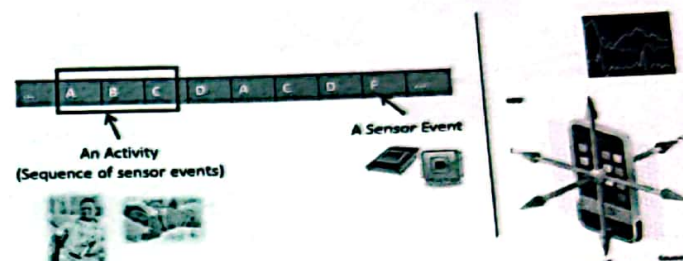
## Data Sources

- Different mediums generate different types of data



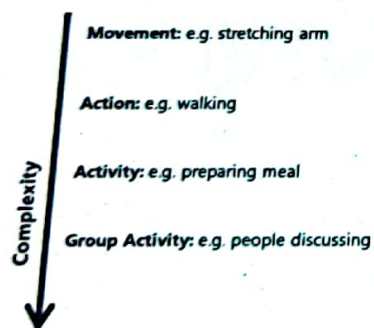
## What is Activity Recognition?

- The basic building block in many applications
  - Recognizing user activities from a stream of sensor events



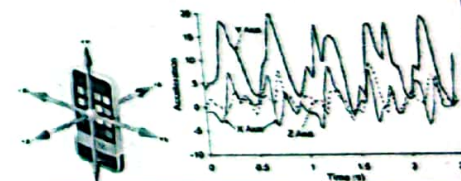
## Activity Resolution

- Fine grained (individual movements, especially in vision)
- Coarse grained (activity)



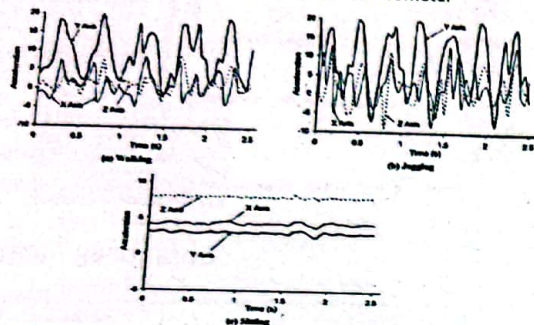
## Activity Data from Wearable Sensors

- Mostly in form of time series
  - Accelerometer [& gyroscope]
- Most actions in form of distinct, periodic motion patterns
  - Walking, running, sitting,...
- Usual features
  - Average, standard deviation
  - Time between peaks, FFT energy
  - Correlation between axes
  - ...



## Example Activities

- Example activities from mobile phone accelerometer



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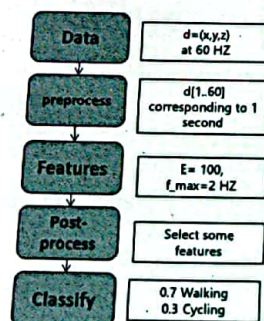
## Processing Steps

- Stages
  - Data collection
  - Preprocessing
  - Feature extraction
    - Mean, SD, FFT coefficients
  - Dimensionality Reduction
  - Classification

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## Processing Steps

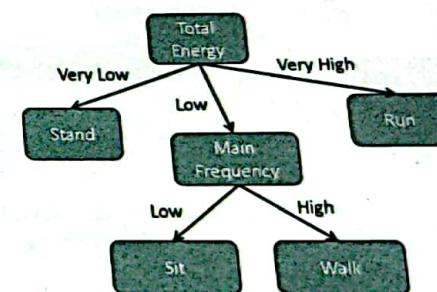
- Stages
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## Classification

- Supervised
  - SVM, DT, ...
- Unsupervised
  - Clustering
  - Motif discovery



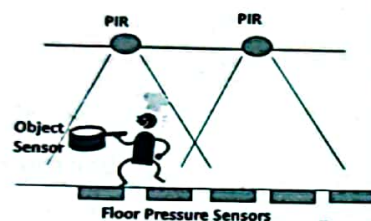
A simple decision tree

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## Activity Recognition

- More complex activities need more sophisticated sensors
  - Sensor networks of PIR sensors, contact switch sensors, pressure sensors, object sensors, etc.
- Approaches
  - Supervised
    - Probabilistic
    - Credibilistic
    - others
  - Unsupervised



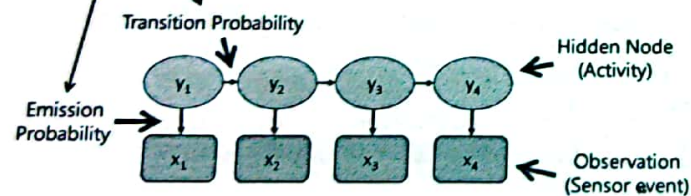
## Classification approaches

- Probabilistic approaches-Graphical models
  - Naive Bayes (NB)
  - Hidden Markov Model (HMM)
  - Dynamic Bayesian Network (DBN)
  - Conditional Random Field (CRF)
- Other models
  - MLP
  - SVM
  - kNN
  - DT
  - FIS
- Credibilistic models

## Hidden Markov Model (HMM)

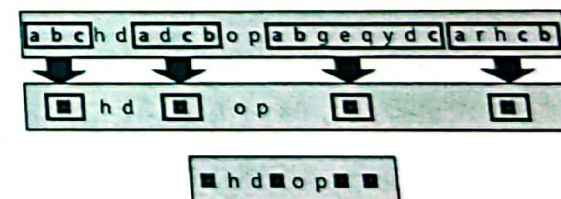
- A model for inferring hidden states from observations
- Well known, efficient algorithms

$$P(y, x) = \prod_{t=1}^T P(x_t | y_t) \cdot P(y_t | y_{t-1})$$



## Unsupervised Methods

- Data annotation problem!
- Emerging patterns
  - Mining frequent patterns
  - Mining periodic sequential patterns
- Stream mining
  - Tilted time model



## Context Information

- Different types of context data
  - Information from sensors
  - Activities and their structure
  - User profile & preferences
  - Static data (e.g. rooms)



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## Context Modeling Approaches

1. Key-value models  
e.g. Context Modeling language (CML)
2. Simple markup schema  
e.g. HomeML
3. Ontology  
e.g. SOUPA, CONON ("Generalized Ontology", "Domain Specific Ontology")
4. Uncertain context  
e.g. Meta-data (e.g. freshness, confidence, resolution)
5. Situation modeling & reasoning  
e.g. Situation calculus, Event Calculus

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## Indoor Location Identification

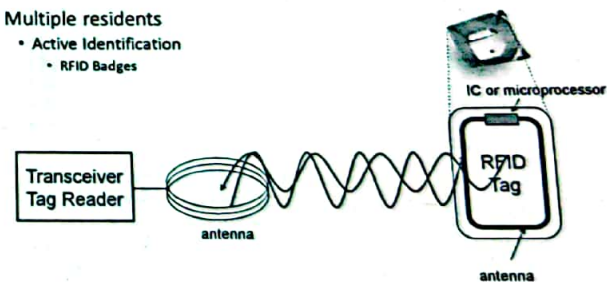
Method	Disadvantage
Smart floor	Physical reconstruction
Infrared motion sensors	Inaccurate, sensing motion (not presence)
Vision	Privacy
Infrared (active badge)	Direct sight
Ultrasonic	Expensive
RFID	Range
WiFi	Interference, inaccurate
Lifi	



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## Person Identification

- Multiple residents
  - Active Identification
    - RFID Badges



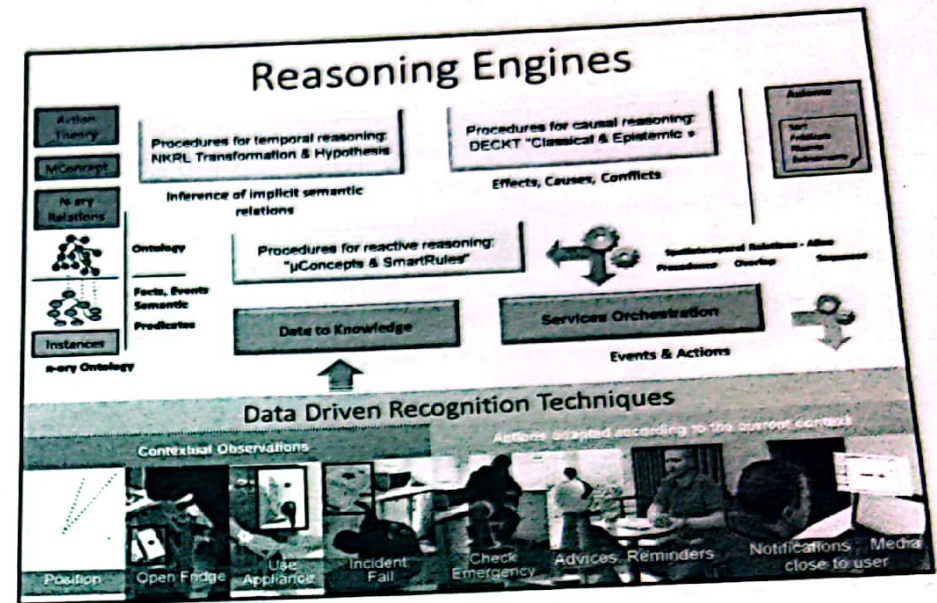
- Anonymous
  - Motion models: physical recognition activity, gait biometric analysis

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## Use Case: Ambient Cognitive Assistance

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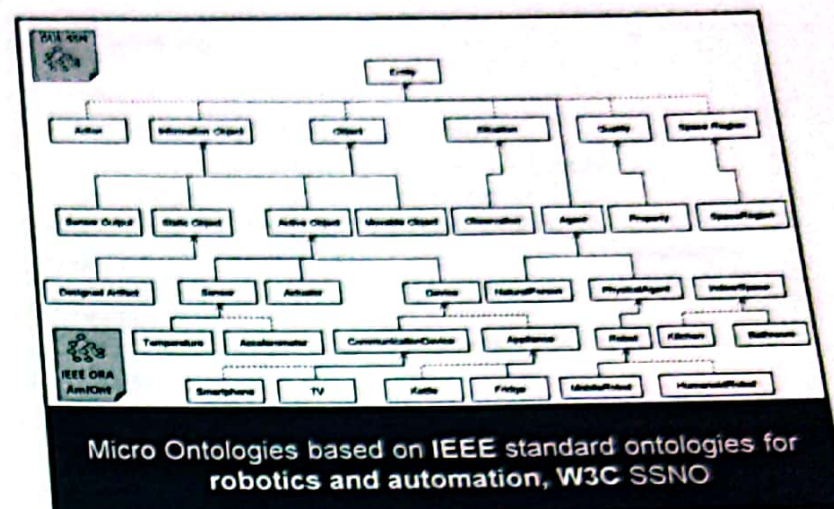
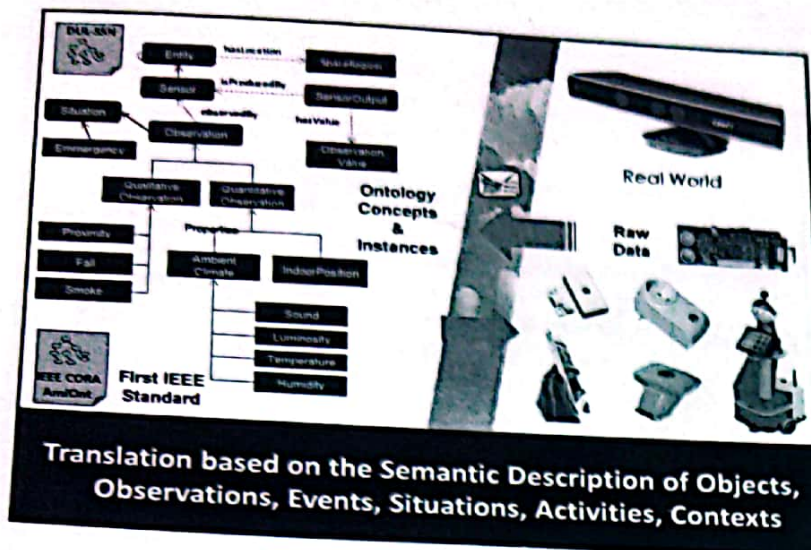
## Ambient Cognitive Assistance: Main issues

- 1) Data Driven Knowledge Management
  - Machine Learning, Data Fusion
- 2) Commonsense Knowledge Driven Management
  - **Static entities** : What the real world composed of ?
  - **Dynamic entities**: How the entities change, evolve and behave
  - **Ontology Languages**
    - Efficient for Sharing Knowledge Between Heterogeneous Agents
  - **Decision** → Close to Human Reasoning
    - Logic Programming & Rule languages
- 3) Abstraction of Aml & Robotics Technologies → Middleware

## Commonsense Knowledge

- Objects at the Conceptual Level Vs Physical Objects in the Real World
  - Semantic description of Physical Objects, Software Components & Services
- Semantic description of Characteristics, Affordances/Services, Significance, Impact and Relevance
- Not Only Static Things but Also Dynamic
  - Dynamic Things: Events, Actions, Interactions, ..
  - Semantic Description of the Spatio-temporal Context
    - Spatial Relations between Objects and Spaces
    - Temporal Relations between events

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### From observations to context

#### • Observations:

- *PostureObservation* (Kinect Sensor+Activity Rec. module provide the pattern *Person\_LyingDown*)
- *Fall* (Fall Sensor)

#### • Context:

- Location, Presence Near to Furniture (Bed, Sofa)
- Accessibility to space

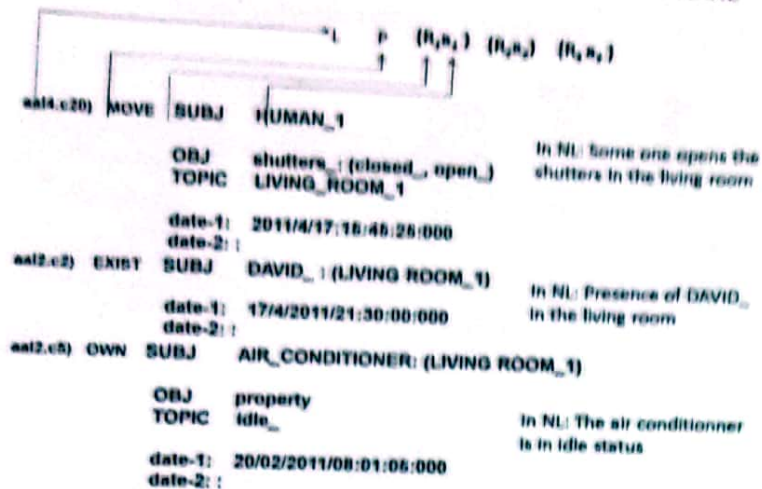


### Commonsense Knowledge

- Use of NKRL Ontology language to describe static as well as dynamic entities
  - Objects, Spaces & their features
  - Events/Actions that are temporally and spatially bounded
  - Human-Agents Dialogues
- In depth (n-ary) conceptual representation of the inner meaning of static and dynamic entities using NKRL ontologies (H\_Class, H\_Temp) ;



## Examples of elementary events representation in NKRL



## Commonsense Knowledge Automated Management

### Commonsense:

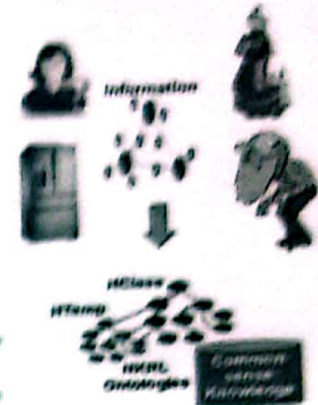
- Humanoid is a mobile robot
- Kompai is a humanoid
- Does Kompai a mobile robot? Yes!
- Representation with Hclass ontology

### Static Entities

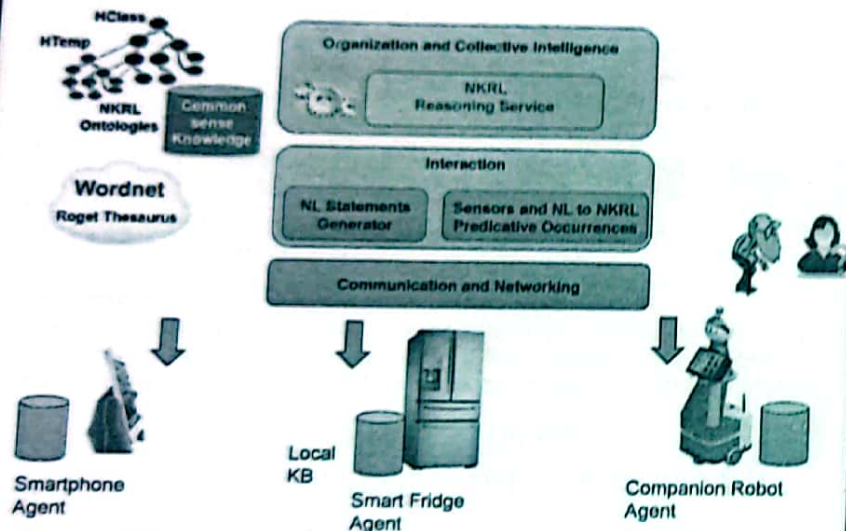
Event: Julia's smartphone sends an information about Julia's location

- n-ary relationship
- Representation with Htemp ontology

### Dynamic Entities



## Distributed Cognitive Architecture

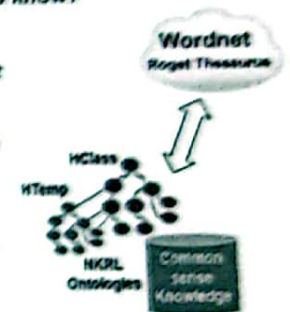


## If ambiguity Agents Rely on Wordnet

- Milk is a dairy product.
- Yogurt is a new term!  
Yogurt is a dairy product, but how do we know?

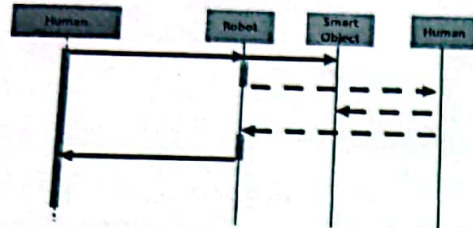
Wordnet: Hypernym (Yogurt) = dairy product  
 → Yogurt is a dairy product

- Dairy product is a substance that can be used or prepared for use as food.
- Yogurt can be used or prepared for use as food



## Advanced Interaction: Solving Missing Knowledge Issue

When an agent fails in providing an answer by querying its local knowledge base, it decides to ask the closest Agent to get the missing information and forward the answer to the user: **Selection of the agent based on its capabilities**



## Reasoning Framework: NKRL Transformation Rule (PAL 2012)

Antecedent :

COORD (C1 C2)

C1: EXIST SUBJ : var1 : var2

var1: human being

var2: supermarket building

C2: PRODUCE SUBJ: var3 :

OBJ : notification message

TOPIC: SPECIF (entity (SPECIF cardinality none ))

var3: basic food

Consequent :

C3: MOVE SUBJ ROBOT:

OBJ notification message

BENF var1

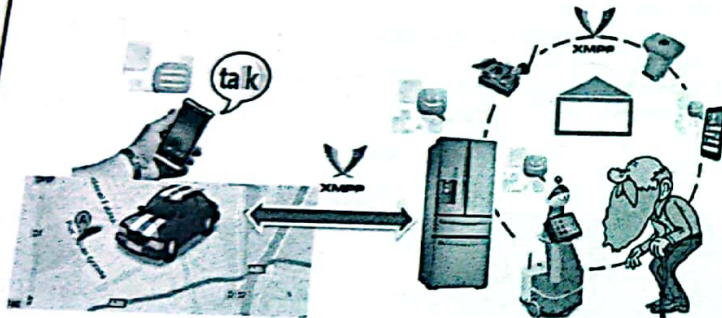
TOPIC SPECIF{ var2 (SPECIF cardinality none )}

var1: human being

var2: basic food

Move:GenericInformation

## Solving the milk issue



<https://youtu.be/I361szW0LM4>

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A Living Lab for experimenting Ambient Assisted Living Services

[http://www.lissl.fr/ubistruct/living\\_lab](http://www.lissl.fr/ubistruct/living_lab)

UPEC LISSl

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Ubistruct: experimental platform  
for ubiquitous robotics

<https://www.youtube.com/watch?v=XicBDjGSxYc>

Assistance scenario

<https://www.youtube.com/watch?v=l361szW0LM4>

