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Dem@Lab: Ambient Assisted Living Framework for the Assessment of Dementia in Clinical Trials

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Outline

1. Problem Area & Contribution
2. AI Requisites
3. The Dem@Lab Solution
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Problem Area & Contribution

Problem

- Key clinical feature of the Alzheimer's disease: Impairment in daily function, reflected on the difficulty to perform complex tasks, such as the **Instrumental Activities of Daily Living** (IADLs) [1]
  - making phone calls
  - shopping
  - preparing food
  - housekeeping
  - laundry
- Current assessment methods involve questionnaires and clinical rating scales

Cannot often provide objective and fine-grained information

- Pervasive and IoT technologies promise to overcome such limitations

Using sensor networks and intelligent analysis to capture the disturbances associated with autonomy and goal-oriented cognitive functions

Our Solution

Dem@Lab, a pervasive framework for monitoring IADL activities in a dementia assessment scenario

- Follows an ontology-driven approach to IoT data modelling and analysis
- Interpretation and assessment are performed

Existing Approaches

- OWL has been widely used for modelling human activity semantics [2]
- In most cases, activity recognition involves the segmentation of data into snapshots of atomic events, fed to the ontology reasoner for classification
- Time windows [3], slices [4] and background knowledge about the order or duration [5] of activities

Dem@Lab follows a hybrid reasoning scheme, using **DL reasoning** for activity detection and **SPARQL** to extract clinical problems.

- Web cameras to monitor IADL in home [6]
- Framework to evaluate activity performance in a smart home [7]
- Motion sensors in clinics to identify sleep disturbances [8]
- Sensor network deployment in nursing homes to monitor vital signs of patients [9]

Dem@Lab extends these concepts in a unified framework for IoT sensor interoperability.

AI Requisites

Knowledge Representation

- Ontologies

Activity Recognition

- Computer Vision
- Reasoning

Problem Detection

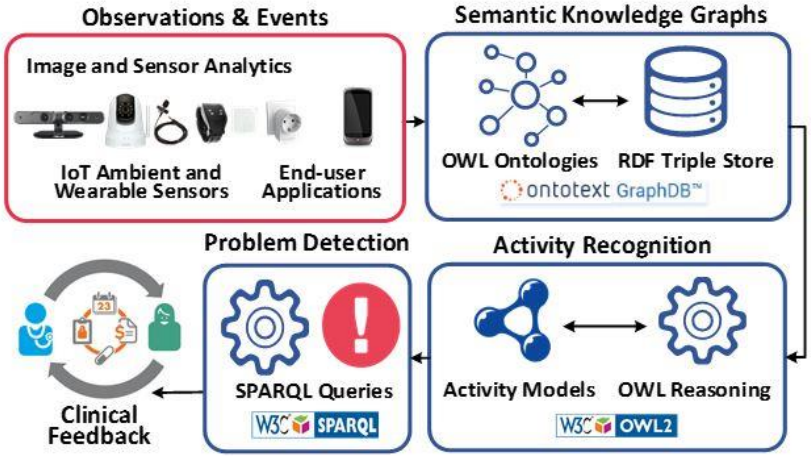
- Outlier Detection
- Rules
- Reasoning

The Dem@Lab Solution

IoT infrastructure

	Device	Sensor Type	Data Type	Modality
	Kinect	Ambient	Image, Depth	Posture, Location, Event
	Camera	Ambient	Image	Posture, Location, Event
	GoPro	Wearable	Video	Objects, Location
	DTI-2	Wearable	Accelerometer	Moving Intensity
	Plugs	WSN	Power Usage	Objects
	Tags	WSN	Object Motion	Objects

Dem@Lab architecture

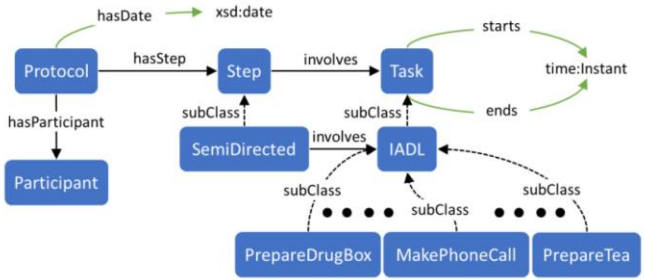


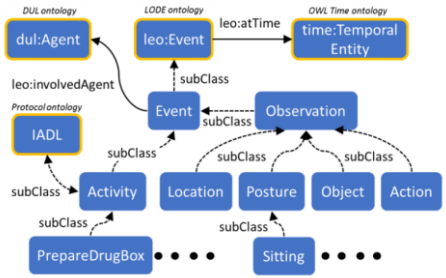
Knowledge Structure and Vocabularies

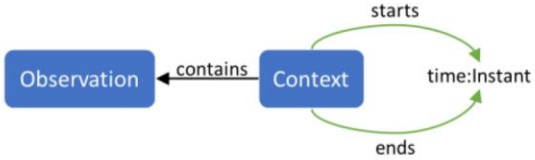
Assessment Protocols

Observations and Activities

Activity Models







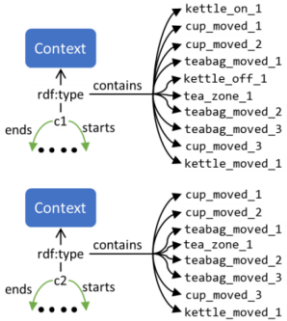
$$PrepareTea \equiv Context \sqcap \exists contains.KettleOn \sqcap \exists contains.CupMoved \sqcap \exists contains.KettleMoved \sqcap \exists contains.TeaBagMoved \sqcap \exists contains.KettleOff \sqcap \exists contains.TeaZone$$

Activity Recognition

Location-driven context generation and classification:

Predefined zones, according to the location each activity takes place. [10]

When a participant enters a zone, a Context instance is generated and associated it with collected observations. The resulting context instances are fed into the ontology reasoner to classify them in the activity hierarchy.



Performance for
7 IADLs and
50 participants

	TP	FP	FN	Recall	Precision
PreparePillBox	45	10	5	90.00	81.82
PrepareTea	38	3	12	76.00	92.68
AnswerPhone	36	4	14	72.00	90.00
TurnRadioOn	41	3	9	82.00	93.18
WaterPlant	41	3	9	82.00	93.18
AccountBalance	40	4	10	80.00	90.91
ReadArticle	45	8	5	90.00	84.91

Problem Detection

- The clinical experts highlighted the fact that, apart from recognizing protocol activities, the derivation of problematic situations would further support them for the diagnosis.

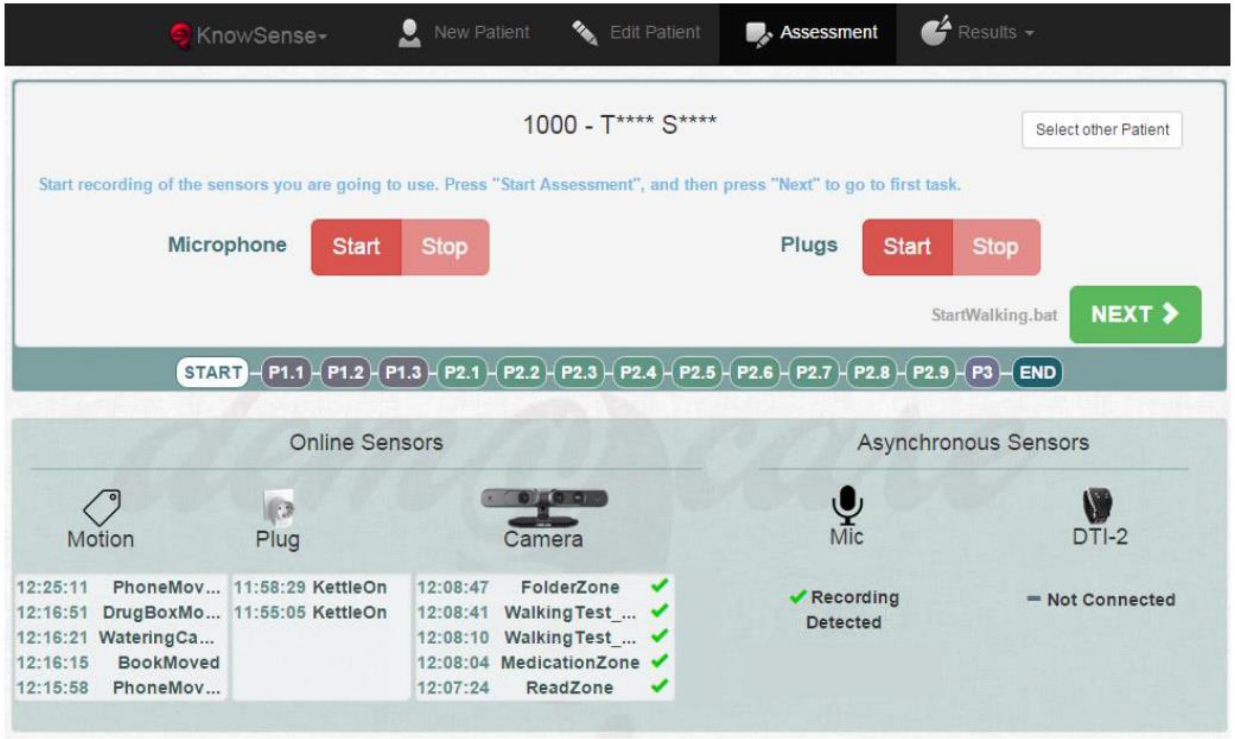
- Dem@Lab has been enriched with a set of **SPARQL** queries to detect and highlight situations of possibly problematic behavior.

Abnormal situations detected include

- Highly repeated
- Excessively long
- Missed (absent)
- Incomplete

```
1: select ?x ?s ?e
2: where {
3:   {
4:      select (count(?o) as ?n) ?x ?s ?e {
5:         ?x a :Context; :contains ?o; :starts ?s; :ends ?e.
6:         FILTER NOT EXISTS {?x a :Activity.}
7:      }
8:   }
9:   FILTER (?n > 1)
10:}
```

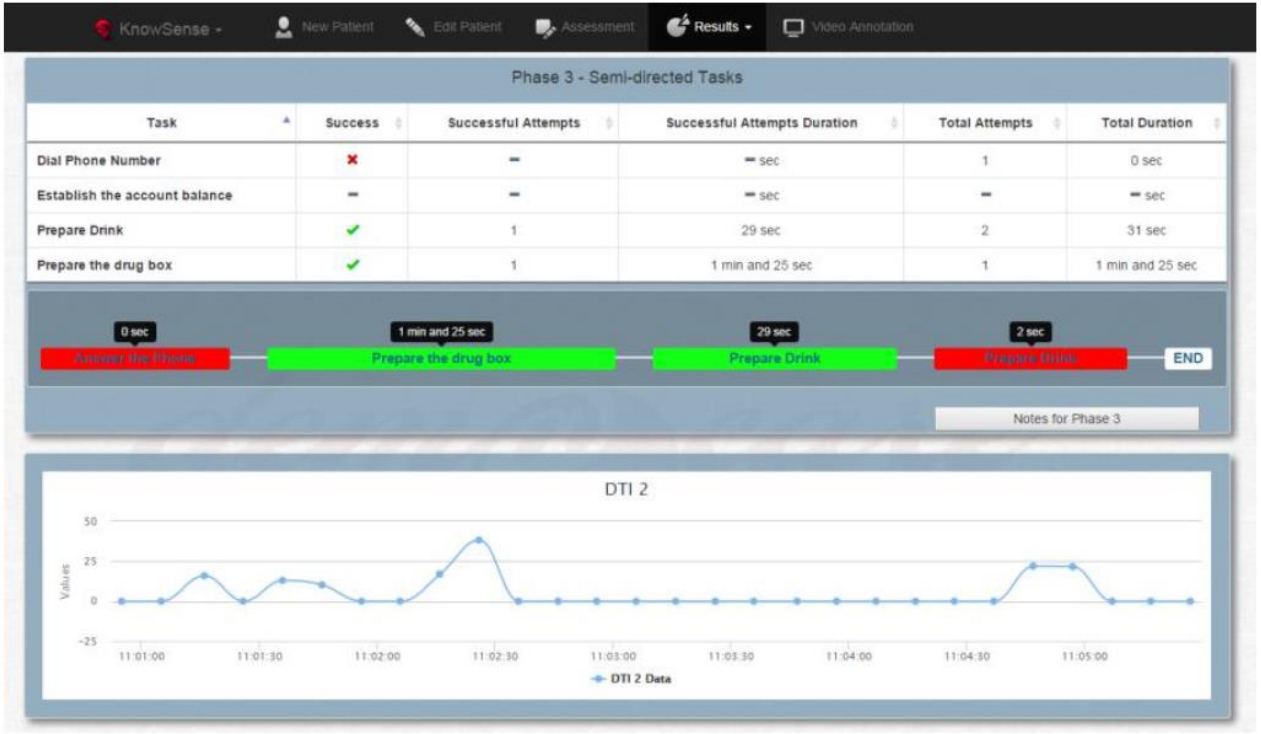
Clinical Interface



Assessment Process

- Automated procedure
- Equipment manipulation and monitoring
- Performed by a single clinician (psychologist) while also instructing or interviewing participants
- Reaching up to 5 participants per day

Clinical Interface



Results

- Complete and incomplete activities with order and duration
- Physical activity measurements

Deployment and Results

Deployed in the day center of the **Greek Association of Alzheimer Disease and Relative Disorders** for more than 100 participants

83% mean accuracy of clinical assessment among healthy, MCI (Mild Cognitive Impairment) and Alzheimer's Disease (AD) [11], compared to direct observation annotation and neuropsychological assessment scores

Alternatives and extensions

- Handle missing information
  - since the current activity recognition models need all axioms to be satisfied
- Handle uncertainty and conflicts
  - as the current approach assumes that all observations bear the same confidence
- Deployment in more realistic, open-world environments, e.g. in homes
  - activity zones are not that clearly predefined and thus it is harder to compensate for sensor errors
  - more items interfering (noise)
  - different actors

Conclusion

Dem@Lab enables complex task monitoring of individuals in a controlled pervasive environment, currently applied in dementia assessment. Underlying AI techniques, computer vision, semantic modelling and fusion, over an IoT infrastructure, provide in-depth information for the duration order and clinical problems during a predefined clinical protocol, assisting in the clinical assessment of autonomy and cognitive decline.

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Thank you!