Detection of Health-Related Problems of People with Dementia from Lifestyle Wearables: A Rule-Based Approach

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Short Resume:

- Researcher at Certh on Semantic Web & Internet of Things (IoT) technologies.
- PhD student at University of Aegean, Department of Information and Communication Systems Engineering, on topic “Semantic Interoperability in IoT”.

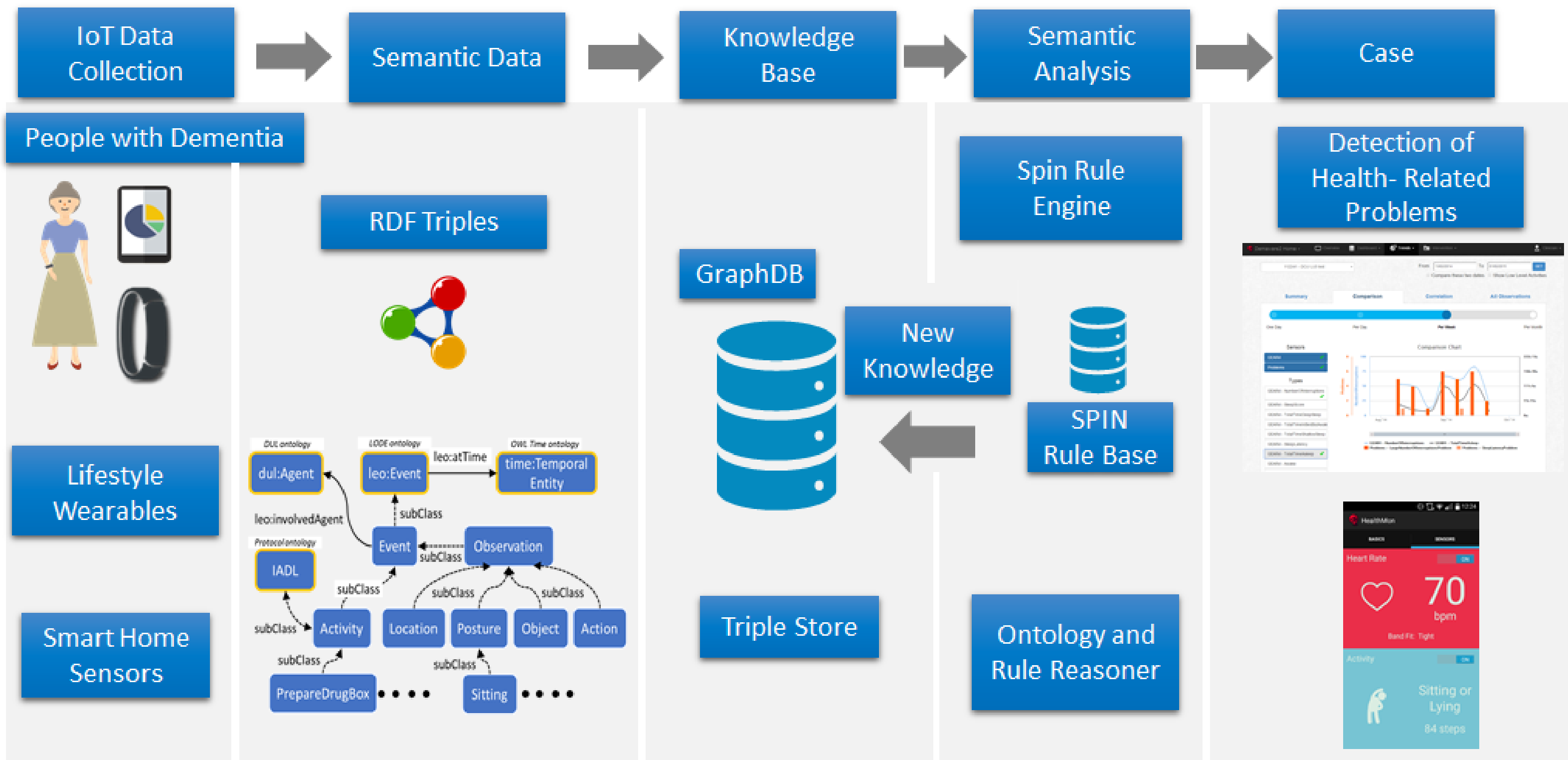
Background

- People living with dementia globally amounted to 50 million in 2019 and are expected to triple to 150 million by 2050 [1].
- A burden on informal caregivers and healthcare professionals to manually monitor lifestyle, and health-related problems such as movement, sleep and stress.
- Framework to map and extract clinical health-related problems is needed [2].
- Semantic technologies provide integrated tools and methods for representing data and producing new Knowledge from them.
- Open research questions include [3][4]:
  - How to integrate Internet of Things sensors and heterogenous data.
  - How can IoT data be analyzed and interpreted to information clinically relevant to dementia.
  - How can this information be visualized for patients, caregivers and clinicians to support self-management and decision making.
  - How can a suitable Reasoner tool, such as the SPIN API, can extract the extra information generated by semantic rules and reuse it.

Related Work

- In previous related studies, Semantic Web technologies have been used to represent knowledge from home healthcare systems.
- Some examples are:
  - Knowsense [6].
  - COSAR [7].
  - ACTIVAGE [8].
  - Dem@Care [9].
  - Faber [2].
  - FallRisk [10].
- The above systems use semantic rule-based mechanisms.
- Provide solutions for activity and event recognition based on the use of ontologies and ontological reasoning.
- Most methods are quite sophisticated and complex to express and to maintain due to rich logic support.

Semantic Reasoning Approach for Heath-Related Problems Detection



Ontology and Knowledge Base

- The goal of an ontology is to semantically represent all concepts related to activity recognition in a healthcare system.
- Semantic information integration model derived from the system's sensors.
- OWL2, Reusing existing models
  - Dem@Care [9].
  - Semantic Sensor Network (SSN) [11].
  - SmartHome [12].
- Supports
  - Atomic activities and measurements by the sensors (e.g. steps, heart rate, sleep).
  - Complex activities inferred through context interpretation (e.g. walking, exercise).
  - Health problems (e.g. sleep problems, emergencies).
- Semantic Data are stored in a Knowledge Base in the form of a triple-store
- We have chosen GraphDB, an enterprise ready Semantic Graph Database, compliant with W3C Standards.

Rule Base 1/2

- Rule Base of the different semantic rules that describe the modeled activities
- In every rule, there are upper and lower limits that control whether a condition is satisfied or not.
- The numerical values of the limits were decided after consultation of the clinicians and the patient users.
- Health Problem Examples
  - Restlessness: high number of sleep interruptions in the night.
  - Stress or Pain: high HR for long without movement.
  - Lack of Movement: low step count in a day.
  - Lack of Exercise: HR out of cardio zone for a day.
  - Insomnia: high sleep latency in the night.
  - Lack of Sleep: short sleep duration in a day.
  - Too much sleep: long total sleep in a day.
  - Increased Napping: too long napping in a day.

Rule Base 2/2

Variables (number)	Rule	Problem
Duration in minutes	Time to fall asleep in a day > 1800	Insomnia
Count of sleep interruptions	Number of interruptions in a day > 10	Restlessness
Duration in minutes	Sleep total duration in a day> 480	Too much sleep
Duration in minutes	Sleep total duration in a day < 300	Lack of sleep
Duration of “Nap” state in minutes	Asleep in Naps > 100 in a day	Increased Napping
Occurrence of “Nap” State, Occurance of “Night Sleep” state	Asleep in Naps end time < 2 hours from Sleep start time	Nap close to bedtime
Time Alseep / Time in bed	Sleep Efficiency < 85	Bad Quality Sleep
Step count, Heart Rate measure, Duration in minutes	Steps < 50 & Heart Rate > 90 (Fat Burn Zone) for duration > 300	Stress or Pain
Heart Rate measure	HR < 60	Low Heart Rate
Step count, Heart Rate measure, Duration in minutes	Steps <1000 & Heart Rate < 80 for duration > 300	Inactivity
Step count, Heart Rate measure, Duration in minutes	Steps < 500 & Heart Rate < 100 for duration > 800	Lack of Movement
Step count	Steps < 80	Lack of Exercise

Implementation of rules with SPIN 1/2

- The SPIN language[7] was chosen by us to create semantic rules.
- SPIN rules derive high-level activity interpretations.
- It combines concepts from object-oriented languages, query languages, and rule-based systems to describe the behavior of objects on the web of data and the Internet of Things.
- It makes the rules accessible and easy to maintain, extend and share.
- The temporal relations among activities are handled by SPARQL functions.
- The derivation of new composite activities exploits the native capabilities of SPARQL to update the underlying activity model.

Implementation of rules with SPIN 2/2

- We used the TopBraid composer, a tool for modeling and developing semantic data applications, to present the SPIN rules.
- TopBraid allows us to easily develop SPIN rules in the form of SPARQL queries, which are more readable than regular SPIN syntax.
- In practice, the following code block presents a simple semantic rule SPIN that was applied to the system ontology.

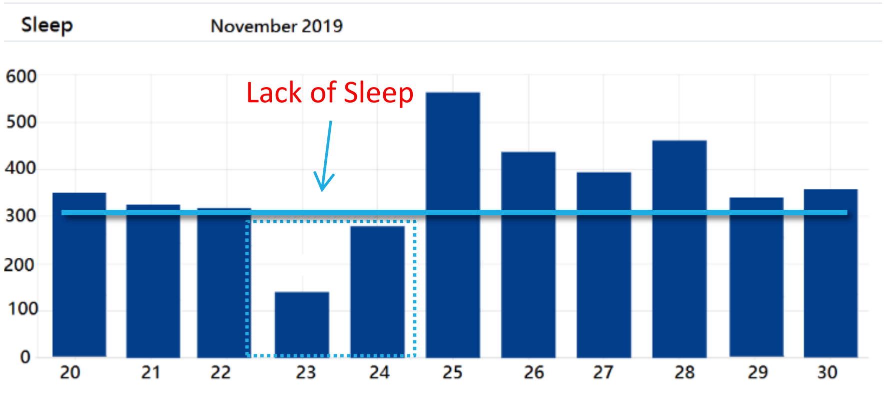
SPIN rule for sleep problem "Lack of Sleep".

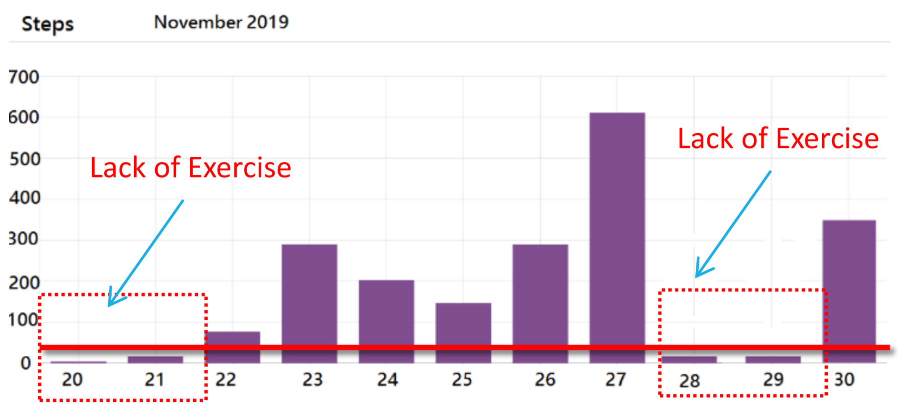
```
CONSTRUCT {
?p owl:hasSleepProblem "Lack of Sleep "}
WHERE {
   ?p a :Person .
                    ?p :duration ?d.
                    FILTER (?d <300 )}
```

Use case 1/2

- A wearable sensor was given to a patient with dementia in order to monitor his activities.
- The duration of the data collection was 11 days (20-30 November 2019).
- The wearables measured sleep duration in minutes and steps per day.
- This data was processed and the results, show health-problems detected.

Use case 2/2


Sleep
November 2019
600
500
400
300
200
100
0
Lack of Sleep
20
21
22
23
24
25
26
27
28
29
30


Steps
November 2019
700
600
500
400
300
200
100
0
Lack of Exercise
Lack of Exercise
20
21
22
23
24
25
26
27
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29
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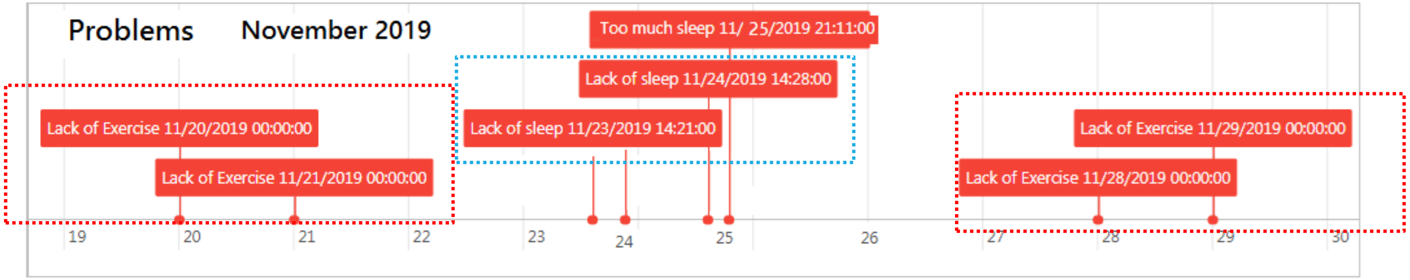
Problems
November 2019
Too much sleep 11/ 25/2019 21:11:00
Lack of sleep 11/24/2019 14:28:00
Lack of Exercise 11/20/2019 00:00:00
Lack of sleep 11/23/2019 14:21:00
Lack of Exercise 11/29/2019 00:00:00
Lack of Exercise 11/21/2019 00:00:00
Lack of Exercise 11/28/2019 00:00:00
19
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Conclusions

- We presented our approach towards the definition of a semantic system for Health-related Problem detection that combines ontologies and SPIN Rules.
- The main purpose of the proposed architecture is to generate new knowledge from the original raw data, especially recognition of health-related problems in patients with dementia.
- The system is validated through a proof-of-concept deployment where a wearable sensor gathers data from a real subject and the framework extracts the expected health-related problems.
- Future Work
  - Clinical study to evaluate the clinical benefit of the system.
  - The framework will be used to extract problems and clinical experts will evaluate its accuracy, usability and usefulness for the disease.
  - In the long run, it will support decision making of the clinicians adjusting their non-pharmaceutical interventions, e.g., a clinician can “prescribe” exercise for lack of activity or relaxation exercises for stress, insomnia and lack of sleep problems.

Thank you for your attention!

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