Agenda

• Introduction & Motivation

• State of The Art & Main challenges

• Contributions: M3 framework
  – Components
  – Use case
  – Evaluation
  – Demonstration

• Conclusion & Future work
How to interpret Internet of Things (IoT) data?

Sensor data

Interpretation by humans

Thermometer

Applications to visualize data

Machine learning?
Reusing domain knowledge?
How to combine and reuse IoT data from different domains?

How to combine and get additional information?

- Milk contains lactose
- Oven, body, external temperature?
- Cross-domain IoT Application: Suggest home remedies according to health measurements
- Cross-domain IoT Application: Suggest safety equipments in your car according to the weather

How to describe data from different domains?

- Smart home & smart kitchen sensor network
- Health sensor network
- Weather forecasting sensor network

How to build innovative applications?

- 1 liter: milk
- 1 kilo: orange
- 110°C
- 38.7°C

1 liter: milk

5 g/L: cholesterol

30 steps

38.7°C
How to describe data and get additional information?

=> Taking inspiration from the Web

Automatically built by machines
How to apply semantic web technologies to Internet of Things?

- Machine-understandable data
- Describe data with common vocabularies
- Reuse domain knowledge
- Link to other data
- Ease the reasoning

How to provide a common description of sensor data to later reason on it?

“Semantic Web of Things: an analysis of the application semantics for the IoT moving towards the IoT convergence” [Jara et al. 2014]
Our contribution: Machine-to-Machine Measurement Framework (M3)

Challenge A: Design semantic based IoT applications

Challenge B.1 & B.2: Combine data and domains

Challenge B.2: Reuse domain knowledge

Challenge B: Interpret IoT data
**SWoT generator**

=> Benefits: No need to learn semantic web technologies

* Domain where is deployed the sensor, not the applicative domain

1) Design SWoT application?

- E.g., temperature & health
- Provide sensor & domain
- Suggest templates*
- Choose template

M3 Framework

**Challenge A: Design semantic based IoT applications**

Generate SWoT template
E.g., Suggest home remedies template
SWoT template: interoperable domain knowledge

- Need to have the set of files generated in the template compatible with sensor data
  - Ontologies + datasets + rules + sensor data
  - Domain knowledge structured in the same way
M3 language & ontology

Challenge B.1 & B.2: Combine data and domains

- Describing data in an unified way
- Extension of the W3C Semantic Sensor Networks (SSN) ontology (Observation Value concept)
- Provide a basis for reasoning and cross-domain interlinking
Sensor-based Linked Open Rules (S-LOR)

Challenge B: Interpret IoT data

3) Interpret IoT data?

E.g., BodyTemperature 38 DegreeCelsius
E.g., Suggest home remedies template

Provide M3 data + SWoT template

Get Smart M3 data or M3 suggestions

E.g., Fever -> Honey & Lemon
S-LOR: Deducing new knowledge

• How to deduce new knowledge?
  – S-LOR: a dataset of interoperable SWRL rules

• Rules example:
  – If `Domain == Health && MeasurementType == Temperature`
    then `NewType = BodyTemperature`
  – If `BodyTemperature > 38.7°C` then “Fever”

• `BodyTemperature` and `Fever` are already described in
domain ontologies or datasets!
Challenge B.2: Reuse domain knowledge
LOV4IoT

A second life for ontologies!

- A dataset of 278 ontology-based projects relevant for IoT
  - Ontologies, Datasets, Rules, Technologies, Sensors and Domains
  - Used to build the SWoT template
  - Extension of Linked Open Vocabularies (LOV)

http://www.sensormeasurement.appspot.com/?p=ontologies
http://lov.okfn.org/dataset/lov/
M3 semantic engine: An entire chain to interpret IoT and build cross-domain applications

Use Case: Embedding M3 in smart fridges

M3 suggestions:
- Home remedies
- Get temperature measurement

Stop to be sick with M3!

M3 suggestions: Home remedies
Evaluating M3 software performances

• Goal: The semantic engine is not too resource consuming
• Evaluation: Measuring time consumed
• Results: Encouraging (16 – 31 ms)
• Could be embedded on Android-powered device

M3 reasoning performance according to the number of rules
Demo

Machine-to-Machine Measurement (M3) is a framework to semantically annotate and easily interpret Internet of Things (IoT) data. M3 enables to design interoperable domain-specific or cross-domain Semantic Web of Things (SWoT) applications.

M3 is composed of the following components:

- SWOT Generator
- LOV4IOT
- S-LOR
- M3 Language
- STAC

http://sensormeasurement.appspot.com
Conclusion & Future work

- M3 hides semantic web technologies to the users
- M3 generic enough for other domains than IoT
Thank you!

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- http://sensormeasurement.appspot.com/
- Slideshare
- Twitter