Assisting IoT Projects and Developers in Designing Interoperable Semantic Web of Things Applications

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• **Introduction & Motivation**
  - Combining Semantic Web technologies and Internet of Things (IoT)

• **State of The Art & Main challenges**
  - The Machine-to-Machine Measurement (M3) Framework

• **Contribution:**
  - Semantic Web of Things (SWoT) generator

• **Conclusion & Future work**
How to build interoperable IoT applications?

Interoperability on data rather than protocols

Cross-domain IoT Application:
Suggest food according to the weather

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

=> Interoperability on data rather than protocols
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

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

Interoperable semantic-based IoT applications

Interoperable knowledge base

Lessons learnt from this catalogue of domain knowledge

Interoperable security knowledge base

http://sensormeasurement.appspot.com/
Semantic Web of Things (SWoT) generator

Template used in 3 steps:
1) Designing phase
2) Development phase
3) Running phase

=> Benefits: No need to learn semantic web technologies
SWoT Generator: Designing phase

1) Design SWoT application?

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

M3 Framework

Design semantic based IoT applications

- Sensor
- Domain
- Rules for M3 converter
- Rules to get high-level abstractions
- Domain ontologies
- Domain datasets
- SPARQL query

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

SWoT template dataset (RDF):
SWoT Generator: Development phase

1) Load:
   - M3 ontologies
   - M3 IoT data
   - M3 datasets

2) Execute M3 rules + reasoning engine

3) Execute M3 SPARQL query + SPARQL engine

4) Get M3 suggestions or high level abstractions

Steps Before
- Get template
- IoT developers

Semantic Web Framework
SWoT Generator: Running phase

Interoperable semantic IoT data

Reasoning engine

E.g., temperature 38°C
E.g., Suggest home remedies template
Provide IoT data + SWoT template
M3 converter
M3 data

Data enrichment + Get M3 suggestions
E.g., Fever -> Honey & Lemon

Standardizing Generic Cross-Domain Applications in Internet of Things [Gyrard et al. 2014]
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
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:

<table>
<thead>
<tr>
<th>SWOT Generator</th>
<th>LOV41OT</th>
<th>S-LOR</th>
<th>M3 Language</th>
<th>STAC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generating SWoT applications</td>
<td>Reusing domain knowledge</td>
<td>Interpreting IoT data</td>
<td>M3 Interoperable IoT Data &amp; Domain Knowledge</td>
<td>Securing IoT applications</td>
</tr>
</tbody>
</table>

http://sensormeasurement.appspot.com
Evaluating the SWoT generator

- 7 different datasets with different kind of sensor data
- 22 templates to build semantic-based IoT applications
  - Interpret data
  - Cross-domain applications

<table>
<thead>
<tr>
<th>Sensor measurements and M3 RDF dataset size</th>
<th>IoT Applications (App)/M3 Suggestions:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precipitation + temperature (3 KB)</td>
<td>App 1: Deduce Snow (Weather, rule involving 2 sensors)</td>
</tr>
<tr>
<td></td>
<td>App 2: Safety equipment in car when snowy (Transport)</td>
</tr>
<tr>
<td></td>
<td>App 3: Activities when snowy (Tourism)</td>
</tr>
<tr>
<td></td>
<td>App 4: Clothes when snowy (Tourism)</td>
</tr>
<tr>
<td>Luminosity, wind speed, temperature, humidity, precipitation (8 KB)</td>
<td>App 5: Interpret weather measurements (Weather)</td>
</tr>
<tr>
<td></td>
<td>App 6: Safety equipment in car according to the weather (Transport)</td>
</tr>
<tr>
<td></td>
<td>App 7: Activities according to the weather (Tourism)</td>
</tr>
<tr>
<td></td>
<td>App 8: Clothes according to the weather (Tourism)</td>
</tr>
<tr>
<td></td>
<td>App 9: Food according to the outside temperature (Naturopathy)</td>
</tr>
<tr>
<td>Longitude + Latitude (3 KB)</td>
<td>App 10: Interpret location measurements (Tourism)</td>
</tr>
<tr>
<td></td>
<td>App 11: Find location information and suggest restaurant around (Tourism)</td>
</tr>
<tr>
<td>Blood pressure, body temperature, cholesterol, heartbeat, skin conductance (5 KB)</td>
<td>App 12: Interpret health measurements (Health)</td>
</tr>
<tr>
<td></td>
<td>App 13: Home remedies according to the body temperature (Naturopathy)</td>
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<tr>
<td></td>
<td>App 14: Deduce mood according to the external luminosity (Emotion)</td>
</tr>
<tr>
<td></td>
<td>App 15: Deduce mood from heartbeat, skin conductance and blood pressure (Emotion)</td>
</tr>
<tr>
<td></td>
<td>App 16: Deduce symptoms/diseases from heartbeat, skin conductance and blood pressure (Health)</td>
</tr>
<tr>
<td>Home dataset: Room temperature, sound (6 KB)</td>
<td>App 17: Interpret home measurements (Home)</td>
</tr>
<tr>
<td></td>
<td>App 18: Interpret temperature or sound data (Home)</td>
</tr>
<tr>
<td>Luminosity + presence (3 KB)</td>
<td>App 19: Switch on/off light if nobody (Home, rule involving 2 sensors)</td>
</tr>
<tr>
<td></td>
<td>App 20: Deduce if someone is in the room or not and switch on/off light (Home, actuation suggestion)</td>
</tr>
<tr>
<td>Food (3 KB)</td>
<td>App 21: Detect food in the kitchen (Smart Fridge)</td>
</tr>
<tr>
<td></td>
<td>App 22: Recipe according to the food available in your kitchen (Home)</td>
</tr>
</tbody>
</table>

http://sensormeasurement.appspot.com/?p=naturopathy
Evaluating the SWoT generator

- **Do we have templates covering the most popular IoT use cases?**

<table>
<thead>
<tr>
<th>Project Name</th>
<th>Name application &amp; Goal</th>
<th>Domain &amp; Sensor used</th>
<th>Download M3 IoT application template</th>
<th>M3 Scenario</th>
<th>Reusing domain knowledge (see LOV4IoT web)</th>
</tr>
</thead>
<tbody>
<tr>
<td>City Pulse</td>
<td>Chronic disease: Monitor food consumption disease = hyperglycemia</td>
<td>Health domain Body temperature, pulse, blood sugar sensor, RFID on food</td>
<td>M3 IoT Appl: BodyTemperature -&gt; Symptom -&gt; Home remedies (6 rules referenced, naturopathy + health ontology and datasets used)</td>
<td>See Naturopathy scenario</td>
<td>See LOV4IoT section Healthcare ontologies</td>
</tr>
</tbody>
</table>

- **Adding a new template?**
  - Less than 1 day
  - Depends on whether we already have the interoperable domain knowledge

http://www.sensormeasurement.appspot.com/?p=m3_scenario
Conclusion:
Semantic Web of Things (SWoT) generator

• Encourage IoT developers to integrate semantic web technologies to reduce development cost:
  ➢ Semantically annotate IoT data
  ➢ Interpret IoT data
  ➢ Reuse domain knowledge available on the Web
  ➢ Interoperability among IoT applications and applicative domains

=> This work is reused within the FIESTA-IoT EU project
Future work

- Composition of templates
- Global interoperability
- Linked Open Services
- More templates inspired from EU project’s scenarios
- Common description
- Device Abstraction
- Common App. Protocol
- Common Nwk. Protocol

⇒ Our proposed approach
Thank you!

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