Using Knowledge Graphs for Machine Learning in Smart Home Forecasters Early PhD Symposium paper

Roderick van der Weerdt, June 7th 2021





IoT Devices are Disconnected











Research Questions Main RQ

Can we improve the accuracy of prediction algorithms by integrating heterogeneous IoT & Smart device data and background knowledge?

Research Questions Subquestions

- Combine the data
 - RQ1: Is SAREF an appropriate ontology to model heterogeneous IoT data?
- Use the data in forecasters
- Include external data
 - divers knowledge?
 - ullethomes)?

• RQ2: Which prediction algorithms are best suited for training on the IoT data knowledge graph?

RQ3: Can we improve the accuracy of forecasters by learning over a heterogeneous set of

RQ4: Can we maintain the accuracy of forecasters with federated learning (over other smart

Interoperability Framework Classic setup



Interconnect



Interoperability Framework New approach





Combine the data Use the data in forecasters Include external data

RQ1: Is SAREF an appropriate ontology to model heterogeneous IoT data?



Combining the Data Issue: Heterogeneous Smart Device Data

Timestamp	State
2020-12-11T12:50:59.076Z	On
2020-12-11T13:05:23.546Z	Off
2020-12-11T13:20:45.789Z	Off





Combining the Data Smart Data Knowledge Graph



Combining the Data Experiments

residential2_circu lation_pump	residential2_di shwasher	residential2_ freezer	DE_KN_reside ntial2 grid imp	DE_KN_residentia	DE_KN_residentia	DE_KN_reside ntial3 dishwas	DE_KN_resid ential3 freez	DE_KN_reside ntial3 grid exp	DE_KN_reside ntial3 grid imp	DE_
574.294	274.137	79.112	309.703	1259.566	973.586	366.268	3734.744	4652.220	5997.692	
574.296	274.137	79.123	309.703	1259.598	973.589	366.268	3734.744	4652.380	5997.692	
574.296	274.138	79.134	309.703	1259.661	973.591	366.268	3734.744	4652.830	5997.750	
574.296	274.74	79.148	309.703	1259.722	973.594	366.268	3734.824	4653.235	5998.011	



Combining the Data Experiments

@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#>
@prefix saref: <https://saref.etsi.org/core/>
@prefix om: <http://www.wurvoc.org/vocabularies/om-1.8/>

<URI_M> rdf:type saref:Measurement; saref:hasValue {INPUT_VALUE} ; saref:isMeasuredIn om:degree_Celsius ; saref:hasTimeStamp {INPUT_VALUE_TIME} ; saref:isMeasurementOf <FEATURE_URI> ; saref:relatesToProperty <PROPERTY_URI> ; saref:measurementMadeBy <DEVICE_URI> .

om:degree_Celsius rdf:type saref:TemperatureUnit .

<PROPERTY_URI> rdf:type saref:Temperature ;
 saref:relatesToMeasurement <URI_M> ;
 saref:isPropertyOf <FEATURE_URI> ;
 saref:isMeasuredByDevice <DEVICE_URI> .

<FEATURE_URI> rdf:type <FEATURE_OF_INT> ;
 saref:hasMeasurement <URI_M> ;
 saref:hasProperty <PROPERTY_URI> .

<FEATURE_OF_INT> rdfs:subClassOf saref:FeatureOfInterest .

<DEVICE_URI> saref:type saref:TemperatureSensor ;
 saref:makesMeasurement <URI_M> ;
 saref:measuresProperty <PROPERTY_URI> ;
 saref:accomplishes <TASK_URI> ;
 saref:hasFunction <FUNCTION_URI> .

<TASK_URI> rdf:type saref:Comfort ; saref:isAccomplishedBy <DEVICE_URI> .

<FUNCTION_URI> rdf:type saref:SensingFunction .

```
refixes:
interconnect: "https://interconnectproject.eu/example/"
saref: "https://saref.etsi.org/core/"
om: "http://www.wurvoc.org/vocabularies/om-1.8/"
ources:
data1:
  access: data.csv
  referenceFormulation: csv
  delimiter: ','
appings
device
  sources: data1
  s: interconnect:DEKNres4_HP
  po:
    - [a, saref:Device]
measurement:
  sources: data1
  s: interconnect:measurement_DEKNres4_HP_$(utc_timestamp)
  po
    - [a, saref:Measurement]
    - [saref:hasValue, $(DE_KN_residential4_heat_pump), xsd:double]
    - [saref:isMeasuredIn, om:kilowatt_hour~iri]
    - [saref:hasTimestamp, $(utc_timestamp), xsd:dateTime]
 featureOfInterest:
  sources: data1
  s: interconnect:featureOfInterest_DE_KN_residential4_heat_pump
property:
  sources: data1
  s: saref:Power
  po:
    – [a, saref:Property]
task:
  sources: data1
  s: saref:Comfort
  po:
    - [a, saref:Task]
 function:
  sources: data1
  s: saref:MeteringFunction
  po:
    - [a, saref:Function]
unitOfMeasurement:
  sources: data1
  s: om:kilowatt_hour
  po:
    - [a, saref:unitOfMeasurement]
```

Experiments Communicating information with SAREF

Thermometer



van der Weerdt, R., de Boer, V., Daniele, L., & Nouwt, B. (2021). Validating SAREF in a Smart Home Environment. Metadata and Semantic Research, 1355, 35.









Experiments **Communicating information with SAREF**



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Combine the data Use the data in forecasters Include external data

RQ2: Which prediction algorithms are best suited for training on the IoT data knowledge graph?



Forecasting with Knowledge Graphs What ML algorithms expect



ML





Dog



Dog: 96% Cat: 44% Bicycle: 12%





Cat

Bicycle

Forecasting with Knowledge Graphs What we Have







Heater on: 82% Heater off: 18%

Forecasting with Knowledge Graphs What we Have





Heater on: 82% Heater off: 18%

Forecasting with Knowledge Graphs How it Will Fit



[0.635, 0.4091, 0.8255,



0.9223]

. . .

[0.6743, 0.5311, 0.3457,

0.9718] Heater on

Heater on: 82% Heater off: 18%



. . .







0.74592] Heater off

. . .



Forecasting with Knowledge Graphs Planned Experiments

Transform the graph into vector representations

 Create Benchmark test comparing multiple state of the art prediction algorithms

Compare prediction algorithms based on accuracy

Combine the data Use the data in forecasters Include external data

RQ3: Can we improve the accuracy of forecasters by learning over a heterogeneous set of divers knowledge?



Forecasting with More Data









Forecasting with More Data Planned Experiments

• Re-train the prediction algorithms from RQ2 with the additional data

Compare the results of the new predictions with the previous results

RQ3: Can we improve the accuracy of forecasters by learning over a heterogeneous set of divers knowledge?

Combine the data Use the data in forecasters Include external data

RQ4: Can we maintain the accuracy of forecasters with federated learning (over other smart homes)?

Forecasting with More Knowledge **Planned Experiments**

learning model

Compare the results of the new predictions with the results from RQ3

RQ4: Can we maintain the accuracy of forecasters with federated learning (over other smart homes)?

Re-implementing the prediction algorithms from RQ2, using a federated

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Thank you

Mapping to Knowledge Graph

Prediction Algorithms using KGs

RQ2: Which prediction algorithms are best suited for training on the IoT data knowledge graph?

RQ3: Can we improve the accuracy of forecasters by learning over a heterogeneous set of Linking with Data

RQ4: Can we maintain the accuracy of forecasters with federated learning (over other smart

Linking with Knowledge

TNO innovation for life

Interconnect